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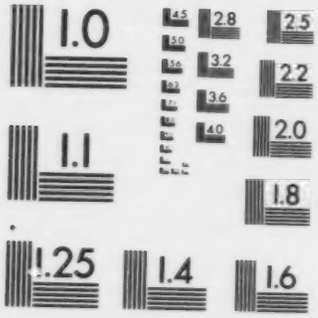
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No 18

Alberta
ENVIRONMENT

preliminary
engineering report

OLDMAN RIVER DAM

Appendix C

RIVER MORPHOLOGY AND SEDIMENTATION

Prepared by

Northwest Hydraulic Consultants Ltd.

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OLDMAN RIVER DAM

RIVER MORPHOLOGY AND SEDIMENTATION

Prepared for:

UMA Engineering Ltd.

Prepared by:

NORTHWEST HYDRAULIC CONSULTANTS LTD.

PERMIT TO PRACTICE
NORTHWEST HYDRAULIC CONSULTANTS LTD.
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The Association of Professional Engineers, Geologists and Geophysicists of Alberta

February 1987

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SUMMARY

A water storage and flow regulation dam is to be constructed on the Oldman River. Studies of the projected morphological changes to the river system resulting from the impoundment of flow by the proposed Oldman River Dam are reported herein. These include:

- reservoir sedimentation;
- river bed aggradation at the head of reservoir; and
- river bed degradation downstream of the dam.

The 4400 km^2 catchment of the Oldman River above the damsite lies between the Continental Divide and the Porcupine Hills. Elevations range from 2800 m at the Divide to 1050 m on the river at the site. Approximately half of the catchment drains to the Upper Oldman River; the remainder of the catchment is divided approximately equally between the Crowsnest and Castle rivers.

Erosion of fine-grained glacio-lacustrine soils provides the greater part of the sediment load in the Oldman River. These fine-grained soils lie mainly along the lower 15 km or so of the Upper Oldman, Crowsnest and Castle rivers. About half of these reach lengths will be drowned by the reservoir. Stream bank erosion and landsliding are the main processes supplying sediment to the rivers.

Suspended sediment data have been collected by Water Survey of Canada, at the Brocket gauging station about 7 km downstream of the proposed damsite, since 1966. Reported annual loads range widely from 7.0 kt in 1977 to 1108 kt in 1975 - the mean value is 266 kt. On average 91% of the annual load occurs during May and June. A value of 320 kt/a has been adopted herein as the long-term mean sediment inflow to the

reservoir, including bedload. In volumetric terms this is equivalent to 320 dm^3/a. Silt and clay make up about 70% of the suspended sediments.

The rate of material slumping from the walls of the reservoir has been estimated by Klohn Leonoff Ltd. for expected reservoir operating conditions during the 40 years or so following completion of the dam. Slumping is expected to be high initially, but decreasing with time. A short reach of the north shoreline of the Oldman River between approximately 2 km and 5 km upstream of the dam site is expected to be the source of 35% of the total shoreline erosion. An average shoreline erosion rate of 240 dm^3/a has been estimated for the first 50 years following completion of the dam.

The reservoir will consist of a narrow 15 km long reach adjoined by three arms formed by the Upper Oldman, Crowsnest and Castle Rivers. At the full supply level of el. 1118.6 m the reservoir has a volume of 490 hm^3 and a surface area 24.4 km^2. It is projected that initially 0.11% of the original capacity will be lost annually due to sedimentation. The half-life of the reservoir is estimated to be about 700 years.

It is predicted that over three-quarters of the sediment will deposit in the Oldman River arm downstream of the present Crowsnest River confluence, and that over half of the sediment will deposit downstream of the Castle River confluence. Approximate sediment deposition volumes in reaches of the reservoir after 50 years of operation are summarized below:

Reservoir Reach	50-year Sediment Deposition	
	Volume hm^3	Fraction of Total %
Upper Oldman	2.3	8
Crowsnest	1.1	4
Castle	2.2	8
Oldman	22.3	80
Totals	27.9	100

A 15 m depth of deposits is expected against the upstream face of the dam after 50 years. Continuous operation of the low level intakes will probably be required to wash sediments through the irrigation tunnels that would otherwise deposit in the area, particularly during the open water season when most slumping of the shoreline will occur.

The effect of proposed reservoir crossings on the distribution of sediment in the reservoir is not expected to affect these figures.

Aggradation at the upstream end of the reservoir where the rivers merge into the reservoir will be minimal because of the low bedload transport of the tributary streams. It is estimated that after 100 years, bed levels in the Upper Oldman River will have increased by a maximum of 2 m and water levels by a maximum of 1 m at extreme flood flows. In the Castle River the corresponding increases would be 1.7 m and 1 m. Aggradation will be insignificant in the Crowsnest River because its bedload transport is negligible.

The bed material of the Oldman River in the reach below the damsite consists of coarse gravel and cobbles. The bed is paved, the surface material being coarser than the sub-surface material. Analysis of the mobility potential of the surface stones show that the surface layer would remain stable except during rare floods. Based on existing conditions the mean annual bed load of the surficial layer is 2.0 kt/a.

Because the bed contains a significant proportion of cobbles that only move during rare floods, it is concluded that degradation of the river bed immediately below the dam will be small. An ultimate degradation of 0.5 m after 25 years is predicted. This would reduce water levels just below the dam by approximately 0.2 m.

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LIST OF ABBREVIATIONS

a	annum (year)
mm	millimetre
m	metre
dm	decametre (10 m)
hm	hectometre (100 m)
km	kilometre
t	tonne
kt	kilotonne
s	second

1. INTRODUCTION

The Government of Alberta is planning to construct a water storage and flow regulation dam on the Oldman River at a site approximately 10 km northeast of Pincher Creek (Figure 1). Responsibility for all engineering aspects lies with UMA Engineering Ltd. and their associate consultant Acres International Limited (UMA-Acres). Northwest Hydraulic Consultants Ltd. (NHCL) was retained as a sub-consultant to assess the sedimentation and river regime aspects of the project. The terms of reference, broadly stated, require determination of:

- rates of sediment deposition in the proposed reservoir;
- aerial distribution of deposited sediments;
- river bed aggradation at the head of the reservoir and its effect on water levels; and
- river bed degradation downstream of the dam and its effect on channel morphology and water levels.

This report presents detailed assessments of these aspects.

2. PRESENT CONDITIONS

2.1 General

Upstream of the proposed damsite, as shown in Figure 1, the Oldman River drains an area of 4400 km^2 lying between the Continental Divide and the Porcupine Hills. Topographic elevations range from 2800 m at the Divide to 1050 m on the river at the site.

The primary river system consists of three major tributaries: the Upper Oldman, Castle and Crowsnest rivers. The Upper Oldman River drains approximately half of the total catchment, while the remainder is split approximately equally between the Castle and Crowsnest Rivers (Table 1).

The mouths of the Castle and Crowsnest Rivers are approximately 10 km and 15 km upstream of the damsite.

2.2 Geomorphic Setting and Erosional Features

The Oldman River catchment has been subdivided into three areas (Figure 1): Mountain, Foothills and High Plains (NHCL, 1980). The present land use and general classification of surficial material in these areas is given in Table 2.

The sources of measured sediment loads in the Oldman River at Brocket (below the damsite) are not well defined. In a reconnaissance report covering the Oldman River basin (NHCL, 1978b) it was concluded that erosion of fine-grained glacio-lacustrine soils provided the greater part of the fine sediment load in the Oldman River. These fine-grained soils lie mainly along the lower 15 km or so of the Upper Oldman, Crowsnest and

Castle rivers (Figure 1) in the High Plains area (NHCL, 1980). Streambank erosion and landsliding appear to be the main processes supplying the sediment to the rivers. Photo 1 shows a typical eroding bank on the Upper Oldman River. Photos 2 and 3 show the lower reaches of the Castle and Crowsnest rivers respectively.

An area of recent massive landsliding exists on the Oldman River 10 km above the Crowsnest River. This has displaced a mass in the order of several million tonnes. The NHCL report of 1978 notes that annual erosion of only a few percent of this mass could account for most of the annual suspended sediment load measured in the Oldman River at Brocket; however it has not been established what proportion of the measured load is actually derived from this source.[1]

The sediment loads supplied from the Rocky Mountains and Foothills areas are considered to be relatively low in relation to the total basin. The soils in these areas are coarse and would not be easily transported over long distances.

In the area of the damsite the Oldman River has formed its valley by downcutting through lacustrine and till deposits into the underlying sandstone (PFRA, 1963). At the damsite the river lies in a steep-walled narrow valley approximately 200 m wide at floodplain level, 400 m wide at top of valley, and 70 m deep (Figure 2). The river has point bars and occasional islands (Photo 4). These forest and shrub covered islands become submerged only rarely.

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1 This landslide area is upstream of the reservoir and so would continue as a source of sediment to the Oldman River after the dam has been completed.

Lateral migration rates of the river at the damsite via erosion of banks are comparatively small - the banks, as shown by Photo 5, contain substantial amounts of coarse material. In some reaches channel shifting is constrained by bedrock outcrops along a valley wall toe (Photo 6).

Bedrock is not exposed in the channel in the vicinity of the damsite. It has been reported that bed material consists of alluvial sand, gravel and cobbles to a depth of about 10 m (PFRA, 1965). Bedrock was, however, encountered at a depth of 2 m below river bed level in a test pit about 1 km downstream of the damsite (Section 2.4.2).

2.3 Hydrology and River Hydraulics

A Water Survey of Canada gauging station is located on the Oldman River near Brocket (5AA-24), only 7 km downstream of the damsite. The recorded mean annual flow is 39.2 m^3/s. Minimum and maximum daily flows over the 1966 to 1984 gauged period are 1.98 m^3/s and 1220 m^3/s respectively.

Table 3 gives the average through-the-year distribution of monthly flows and the division of flow between the three tributaries. May and June are the high flow months and together account for, on average, 57% of the annual flow volume at the damsite. High flows in this period are typically the combined effect of snowmelt and rainfall.

The division of flow between the tributaries is not the same as the division of catchment area. Table 4 shows that while the Castle River drains only 27% of the area it delivers 45% of the annual flow.

Flood frequency estimates for the Oldman River at the damsite and the tributaries at the confluences are given in Tables 5 and 6 respectively. The 100-year flood estimates are summarized below:

River	100-year Flood (daily) m^3/s
Oldman at damsite	1500
Upper Oldman	589
Crowsnest	163
Castle	1170

The estimated probable maximum flood (PMF) for the Oldman River at the damsite is 9320 m^3/s (UMA-Acres 1986).

Figure 3 shows the bed profile of a 3.5 km reach of the Oldman River through the damsite, with water surface profiles for flows of 100 m^3/s to 1500 m^3/s as calculated using the U.S. Army Crops of Engineers HEC-2 backwater program. The calculation utilized 30 cross-sections of the river surveyed by Brown, Okamura and Associates Ltd. during the summer of 1985.[2]

The stage-discharge curve at the diversion tunnel inlet, just upstream of the damsite, is shown in Figure 4. Hydraulic properties of a 1.1 km reach of the main channel between 400 m and 1500 m downstream of the damsite are shown in Figure 5. The river slope downstream of the damsite averages 2.2 m/km.

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2 Cross-section data and plots of the Oldman River and tributaries are given in Appendix A.

Figure 6 shows profiles of the reaches of the three major tributaries that would be inundated by the reservoir. Hydraulic properties of the tributaries in the vicinity of the head of the proposed reservoir are shown in Figure 7.

2.4 Oldman River Sediment

This section is essentially an update and expansion of a 1978 report (NHCL, 1978a). Additional suspended sediment and bed material data have been collected since the earlier report. These, together with the hydraulic geometry of the rivers now available, have enabled firm estimates to be made of the total sediment load of the Oldman River.

2.4.1 Suspended Sediment Data

Oldman River at Brocket. Eighteen years (1966 to 1983) of suspended sediment data are available for the WSC gauging station on the Oldman River near Brocket. These data are summarized and reviewed in a recent report by Environment Canada (1985). Annual loads are listed in Table 7 and plotted in Figure 8: values range widely, from 7.0 kt in 1977 to 1108 kt in 1975. The mean annual load is 266 kt. In contrast, the annual discharge varies by a factor of only four over the same period (Table 7).

Plots of daily or annual loads versus the corresponding discharge show weak correlation. This is to be expected as the suspended sediment, as will be shown later, consists of wash load only: that is, fine material eroded from the catchment, the quantity of which is dependent only in part on discharge. Annual suspended sediment load correlates quite

well however, with maximum monthly discharge (Figure 9), using a logarithmic transformation. Regression lines fitted by the linear least squares technique to such log-transformed correlations tend to under-predict the sediment load when applied to discharge data. For example, the 1966 through 1983 average annual load calculates as 244 kt using the regression line of Figure 9. This is 8% lower than the measured value.

The average through-the-year distribution of monthly loads, given in Table 8 and Figure 10, shows that on average, 91% of the annual load occurs in May and June. These are the months of maximum discharge (Table 3).

On occasion, most of the annual load occurs in only a few days or so. For example, Figure 11 shows the 1975 hydrograph of daily discharge and sediment load for May through July. The peak discharge of 20 June (1220 m^3/s; approximately a 50-year event) probably resulted from localized rainfall in the upper catchment. It is speculated that this flood event triggered the massive landslide on the Oldman River 10 km upstream of the Crowsnest confluence, causing in turn the extreme sediment load peak (NHCL, 1980). The one-day load of 20 June 1975 was 53% of the 1975 total and exceeds all reported annual loads except for 1967 and 1972.

Other sites. Limited suspended sediment data are also available for two of the three major tributary streams; Upper Oldman River near Waldron's Corner (1976 to 1983); Crowsnest River at Frank (1976 to 1980). Table 9 shows April through September suspended sediment loads for these two

stations, together with corresponding data for the Oldman River near Brocket.[3]

The tributary stations are in the upper part of the catchment (Figure 1) as shown in Table 10. If these stations had been closer to the confluence the data would have provided a basis for distributing the annual suspended sediment load at Brocket between the three tributaries entering the proposed reservoir.

Suspended sediment water samples have been collected on the tributary streams in the vicinity of the confluences but only on one day, (23 May 1985) so by themselves do not provide a basis for estimating the load distribution (see Appendix B).

For the five years (1976 through 1980) when there are synoptic data for two of the tributaries (Table 9), the mean sediment yields per unit area are as given in Table 11. The yields from the Oldman above Waldron's Corner and the Crowsnest above Frank are similar (9.3 and 6.2 t/km^2 respectively), but at Brocket the overall yield is approximately three times higher (24 t/km^2). This indicates the existence of a zone in the lower catchment(s) with a yield notably greater than 24 t/km^2. This zone could embrace the Lower Oldman, Lower Crowsnest and possibly the unmeasured Castle River catchments. In consideration of the erosional features mentioned in Section 2.2 and concentration measurements on the tributaries in May 1985, the zone of highest yield is probably adjacent to the

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3 Measurements were not made during the winter months at the two tributary stations, but loads can be assumed to be insignificant during this period. Based on the Oldman River near Brocket record, the April through September load represents 98% of the annual total (see Table 8).

15 km or so of the Oldman River upstream of the Crowsnest confluence. An allocation of suspended sediment as given in Table 12 has therefore been adopted for present purposes.

Grain Sizes. Figure 12 (from Table 13) shows the average grainsize distribution of suspended sediments sampled on the Oldman River near Brocket by Water Survey of Canada. The composition by classes is approximately as given in Table 14, the sediment consisting primarily of silt and sand.

Bed material size data (Section 2.4.2 below) indicate that less than 1% of the suspended sediment could have originated from the river bed. All of the suspended sediment can therefore be classified as wash load.

2.4.2 Bed Material Data

Grain sizes (Oldman River). Bulk samples of bed material collected from three test pits (maximum depth 2.4 m) in the Oldman River, at points located approximately 0.9, 1.5 and 2.4 km downstream of the dam axis, show that in the top 2 m or so the bed material is composed primarily of coarse gravel and cobbles. The locations of the two most upstream pits are shown in Figure 2 and the location and maximum depths of all three pits are indicated on the profile of Figure 3. Competent sandstone bedrock was encountered at a depth of 2.2 m in the farthest upstream pit. Photos 6 and 7 show two of the test pits being dug. Photo 8 shows material obtained from a test pit at a depth of 2 m. Details of the test pit data are given in Appendix C.

The data show that there is only slight variation in the sizes of the sub-surface material, both at different

elevations within the same pit, and from pit-to-pit; and that the surface material is somewhat coarser than the sub-surface (Figure 13). Both the surface and sub-surface materials consist primarily of coarse gravel and cobbles. Average grainsize distributions are given in Table 15.

Imbrication (ie. an alignment whereby the stones overlap each other like roof tiles) of the larger surface stones is visible in Photos 9 and 10, indicating that the river bed is paved and highly resistant to movement. Analysis of the mobility potential of the surface stones, even without special consideration of the imbricated pattern, confirms that the surface layer would remain stable except during rare floods.

Grain Sizes (tributaries). The grain sizes of river bed material at gauging stations located on the Castle, Crowsnest and Oldman rivers upstream of the damsite are given in a Research Council of Alberta publication (Kellerhals et al, 1972). Data indicate that the surface materials are also composed of gravel and cobbles (Table 16).

Bed Material Transport. Estimates of the annual bed material load for the Oldman River at the damsite and the three tributaries in the reach at the head of the proposed reservoir are given in Table 17. The annual load of 2 kt/a for the Oldman River at the damsite comes from the Upper Oldman and Castle rivers only. This is less than 1% of the suspended load.

2.4.3 Mean Annual Sediment Load

A value of 320 kt/a has been adopted as the long-term mean sediment load (including bed load) at the damsite; this is 20% higher than the measured suspended average to allow for the large variance of the data.

3. PROJECT IMPACTS

3.1 General

Damming of an alluvial river can sometimes result in significant morphological changes. The potential for both aggradational and degradational changes is addressed in this section.

3.2 Reservoir Characteristics

The Oldman reservoir will consist of a narrow, 15 km long reach adjoined by three arms formed by the Oldman, Crowsnest and Castle rivers. This is shown schematically in Figure 14. At the full supply level (FSL) of El. 1118.6 m the reservoir has a storage volume of 490 hm^3 and a surface area of 24.4 km^2. The capacity/inflow ratio is 0.40 based on the mean annual inflow of 1240 hm^3.

3.3 Reservoir Sedimentation

3.3.1 Reservoir Sediment Load

The sediment entering the reservoir has two components:

1. sediment transported by the Oldman River; and
2. material slumping from the reservoir banks under the action of gravity.

A long term mean river-borne load of 320 kt/a has been estimated entering the reservoir, assuming that existing

conditions (climate, land use, hydraulics, potential erosion) remain the same in the future.

An assessment of potential erosion from the reservoir shoreline has been made by the Reservoir Consultant for expected conditions during the forty years or so following completion of the dam. Table 18 summarizes the projected erosion rates for various reaches of the reservoir and shows that 70% of the shoreline erosion is projected to occur in the reach of the reservoir between the Castle River confluence and the dam. A short reach of the north shoreline of the Oldman River between approximately 2 km and 5 km upstream of the dam site is expected to be the source of 35% of the total shoreline erosion.

Sedimentation was estimated after 50 years of reservoir operation. For the river-borne load, a value of 16,000 m^3 or 16 hm^3 (50 times the long term estimate of 320 kt/a and assuming a sediment deposition density of 1.0 t/m^3 - see section 3.3.2) was used. For the shoreline erosion load the estimate was based on the values given in Table 18 as follows:

Sum of	Scenario 1-3	load times 20 years
plus	Scenario 4	load times 10 years
plus	Scenario 5	load times 20 years

This amounts to 11,900,000 m^3 or 11.9 hm^3. Therefore, the total estimated sediment volume which will enter the reservoir in the first 50 years of operation is 27.9 hm^3.

3.3.2 Sediment Deposition Pattern

The deposition pattern was estimated by treating the two components of sediment entering the reservoir separately, then summing the effects.

Preliminary simulation of reservoir operation for the 28-year hydrologic period from 1928 to 1955 (South Saskatchewan River Basin Planning Studies as reported in UMA-Acres, 1986) showed that during May and June, when over 90% of the annual river-borne sediment load enters the reservoir, the reservoir water level would be at the full supply level for 26 of the 28 years. It has therefore been assumed that the reservoir level is held at FSL for reservoir sedimentation calculations of the river-borne load.

River-Borne Sediment. Essentially, all of the inflowing sediment will deposit within the reservoir. This conclusion is based on Brune's empirical curve (reported in ASCE, 1975), which gives a reservoir trap efficiency of 96% for the Oldman River capacity/inflow ratio of 0.40.

The pattern of longitudinal sediment deposition was estimated by treating the reservoir initially as three separate reservoirs, then summing the effects, as shown schematically in Figure 15.

The Empirical Area-Reduction Method as reported by Borland (1971) was used to distribute the sediment in the reservoir. This method was based on the analysis of data obtained from resurveys of 30 reservoirs in the United States. It was found that there was a definite relationship between the relative depth and percent of sediment for different types of reservoir based on physical shape.

A density of 1 t/m^3 was assumed for the sediment deposited in the reservoir. This was based on the measured average density of 0.73 t/m^3 for Lake Diefenbaker sediment after 15 years of deposition and consolidation (Yuzyk, 1983), and the density after 50 years calculated using the Miller Formula (reported in ASCE, 1975) of 1.1 t/m^3.

Shoreline Eroded Sediment. It was assumed that the shoreline eroded sediment would essentially deposit in the lower elevations in the reach of the reservoir from where it was eroded. The shoreline erosion volume for specific reaches given in Table 18 were therefore taken as the deposition volumes distributed uniformly across the reservoir.

Total Sediment. Table 19 summarizes the combined 50-year sediment deposition volumes in reaches of the reservoir. Overall, the river-borne sediments account for just over half (56%) of the total sediment load.

Figure 16 plots capacity and area of the total reservoir against water level, for initial conditions and after 50 years of sedimentation. In terms of volume loss, the reservoir will annually lose, on average, 0.11% of its original capacity. At this initial rate of loss the reservoir would have a half-life of about 500 years. In the long term the rate of sedimentation will decrease, primarily because shoreline erosion rates after 100 years should be less than the initial rates. Therefore, the realistic half-life of the reservoir will probably be in the order of 700 years.

Results of the calculations, plotted in Figure 17, show that over half of the sediment will deposit in the Oldman River downstream of the Castle River confluence, and will largely be confined to the lower elevations of the reservoir.

This is further illustrated by the longitudinal profile, Figure 18, that shows sediment depths; deposits of the order of 5 m occurring in the 7 km reach downstream of the Crowsnest River confluence. Against the upstream face of the dam about 15 m of deposits (up to El. 1065 m) are expected after 50 years; these deposits will consist primarily of material eroded from the reservoir shoreline just upstream of the dam.

Theoretically, deposition could be sufficient to cover the low level intakes 400 m upstream of the dam (invert at El. 1048 m). Continuous operation of these intakes will be necessary to wash sediments through the irrigation tunnels that would otherwise deposit in the area, particularly during the open water season when most slumping and erosion of the shoreline will occur.

3.3.3 Effect of Reservoir Crossing Structures

The reservoir sediment deposition pattern could be affected by reservoir crossing structures if ponding occurred upstream of the structures. Some of the suspended sediment that would have been swept further downstream would then deposit upstream of the structure due to the reduced flow velocities in the ponded area. However, restriction of the flow area would be required to cause significant ponding.

The locations of possible crossings of the Oldman Reservoir are shown superimposed on Figure 17. There are two alternate locations across the Upper Oldman River ("B" and "H") and two alternate locations across the Crowsnest River ("I" and

"J"). The most probable option is "H" and "J" and "B", with "I" as an alternate combination.[4]

Table 20 gives the flow areas below the FSL of El. 1118.6 m at the crossing locations for both combinations, with and without crossing structures. In the Upper Oldman, crossing "H" restricts the river the most, reducing the flow area to 87% of its original value. Crossing "B" would reduce the flow area to 93%. On the Crowsnest River crossing "J" restricts the river to 43% of its original area. Crossing "I" does not encroach at all on the river.

The crossings on the Upper Oldman are not expected to affect the sediment deposition in this reach of the reservoir as the flow area would be restricted by only 10%. The restriction would be insufficient to cause significant ponding upstream of either of the crossings.

Crossing "J" is the only crossing of the Crowsnest River that could possibly cause ponding to occur and so affect sedimentation. This is unlikely, however, because the velocities in the arm of the reservoir are very low. At the 2-year flood of 35 m^3/s (Table 6) the velocity through the restricted area is 0.015 m/s, for example. This would not cause significant ponding upstream of the structure. Overall, the estimate of sediment deposition patterns is not expected to be affected by the crossings currently under consideration.

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4 The information on reservoir crossing structures was provided by Stanley Associates Engineering Ltd., the consultant responsible for reservoir related works and specifically the roadway links.

3.4 Aggradation

At the upstream end of the reservoir, in the backwater zone where the river merges into the reservoir, deposition of bed load will form a delta. In time, these increases in bed levels will result in further increases in water levels.

Of the three river channels at the head of the Oldman Reservoir, aggradation will only occur in the Upper Oldman and Castle rivers, as bed load transport in the Crowsnest River is negligible (Section 2.4.2).

Figure 19 is a diagrammatic representation of the projected aggradation in the Upper Oldman and Castle rivers after 100 years. The delta configuration was determined by computing the slope at which the bedload material would no longer be transported. The effect on water levels was calculated by backwater analysis.

In the Upper Oldman River, bed levels will increase by a maximum of 2 m. This will cause water levels to increase by a maximum of 1 m at extreme flood flows. Increases in water levels will have died out within a few kilometres of the head of the reservoir. On the Castle River the bed level will increase by a maximum of approximately 1.7 m. Water levels will increase by a maximum of 1 m, but will have died out within a few kilometres of the head of the reservoir.

The above assessment is based on the reservoir being held at approximately full supply level (Section 3.2, Reservoir Characteristics). Reservoir operation that results in the level fluctuating by say a few metres would cause the

aggradation to be spread over a greater length of channel thereby reducing the projected increases in bed and water levels.

3.5 Degradation

The river bed below the dam will degrade slightly due to the entrapment of coarse sediment in the reservoir. An ultimate degradation of 0.5 m is predicted for the river bed in the reach below the damsite. This conclusion is based on application of the U.S. Army Corps of Engineers HEC-6 computer model and on consideration of stable slopes. It was assumed that:

- peak flows would be similar to present conditions; ie. the reservoir would be effectively run-of-river during high flow events, which are most important for degradation; and
- the surficial bed material that currently protects the bed would be removed to expose the slightly finer underlying material (Figure 13).

Since the sub-surface material contains sufficiently large stones, re-armouring of the bed will occur. The river banks also contain large quantities of coarse material to assist in the armouring process (Photo 5).

Degradation will be limited to a reach of 2 km or so below the damsite. The time to reach the ultimate degradation is estimated as approximately 25 years.

The effect on the tailwater rating curves at the service spillway flip bucket and at the diversion tunnel outlet

are shown in Figures 18 and 19 respectively. The curves are for present and degraded conditions. The effect of the degraded bed level is to reduce water levels by approximately 0.2 m.

4. CONCLUSIONS

4.1 The half-life of the reservoir will be about 700 years.

4.2 Sediment deposition will be greatest in the reach immediately upstream of the dam, and could be sufficient to cover the low level intakes. Continuous operation of these intakes may be necessary to wash sediments through the irrigation tunnels that would otherwise deposit in this area.

4.3 Reservoir sedimentation patterns will not be affected by the proposed reservoir crossing structures.

4.4 Aggradation will occur in the Upper Oldman and Castle rivers only, and is expected to increase water levels after 100 years by about 1 m.

4.5 An ultimate degradation of the river bed of about 0.5 m is expected, and will be limited to a reach of 2 km or so below the dam. The time to reach ultimate degradation is estimated to be about 25 years.

5. RECOMMENDATIONS

5.1 In the assessment of bed degradation downstream of the dam we have assumed that post-dam flood peaks will not be much different than at present. This provides a conservative scenario for degradation potential. However, not addressed in this study is the impact of reservoir operation on tributary sediment in-flow downstream of the dam. If the assumptions with respect to flood peaks holds true, then the ability of Oldman River flows to 'flush' tributary sediment through the system will be sustained. Ultimately a quantified perspective of impacts on flood peaks will likely become available and at that time it is recommended that an assessment be made of the issue regarding tributary sediment.

6. REFERENCES CITED

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TABLE 1

OLDMAN RIVER DAM CATCHMENT AREAS

Tributary Stream	Catchment Area km^2	Catchment Area %
Oldman	2140	48.6
Castle	1210	27.5
Croswsnest	1050	23.9
Totals	4400	100.0

TABLE 2

SURFICIAL MATERIALS AND LAND USE OF THE OLDMAN RIVER CATCHMENT*

Unit	Surficial Materials	Land Use
Mountain	Colluvium and till overlying bedrock	Mostly managed forest, some mining
Foothills	Till blanket over bedrock	Mostly open range, some cultivated land
High Plains	Till and fine-grained glacio-lacustrine soils, local areas of glacio-fluvial and alluvial gravel.	Equal split between open range (high elev.) and cultivated land (low elev.)

* From NHCL, 1980

TABLE 3

MEAN MONTHLY FLOWS FOR TRIBUTARY RIVERS

Month	Mean Monthly Flow Oldman R. Near Brocket	Tributary Flow as Ratio of Oldman River near Brocket[1]		
		Oldman R. - Brocket	Castle R. - Cowley	Crowsnest R. - Lundbreck
	m^3/s	%	%	%
Jan.	7.8	34	40	26
Feb.	8.3	38	37	25
Mar.	12.8	39	35	26
Apr.	30.7	35	43	22
May	132	36	48	16
June	149	39	48	13
July	54.0	40	43	17
Aug.	24.8	42	38	20
Sept.	15.5	41	38	21
Oct.	13.6	36	44	20
Nov.	10.4	35	43	22
Dec.	8.7	33	43	24
Annual	39.2	38	45	17

1 Division of flows based on extended flow data 1912 to 1982 (Alberta Environment, 1982 and 1984)

TABLE 4

TRIBUTARY CATCHMENT AREAS AND ANNUAL FLOWS

Tributary	Percentage of Total	
	Catchment Area %	Annual Flow %
Oldman	49	38
Castle	27	45
Crowsnest	24	17
Totals	100	100

TABLE 5

FLOOD FREQUENCY ESTIMATES
OLDMAN RIVER NEAR BROCKET*

Return Period years	Maximum Discharge	
	Daily m^3/s	Instantaneous m^3/s
2	240	300
5	480	600
10	695	870
25	1005	1255
50	1250	1500
100	1500	1880

* From UMA-Acres, 1986

Note:
- Flood estimates calculated using a log Pearson Type III distribution

TABLE 6

FLOOD FREQUENCY ESTIMATES
TRIBUTARY RIVERS

Return Period years	Maximum Daily Discharge		
	Upper Oldman R.[1] m^3/s	Crowsnest R.[2] m^3/s	Castle R.[3] m^3/s
2	84	35	115
5	160	55	201
10	230	73	302
25	350	102	520
50	456	130	778
100	589	163	1170

[1] Station 5AA1 less 5AA2 for 1909 to 1930

[2] Station 5AA2 for 1909 to 1930

[3] Station 5AA3 for 1910 to 1930

Note:
- Flood estimates calculated using a log Pearson Type III (moments) distribution.

TABLE 7

ANNUAL SUSPENDED SEDIMENT LOAD
OLDMAN RIVER NEAR BROCKET

Year	Annual Suspended Sediment Load	Total Discharge	Maximum Monthly Discharge
	kt	km^3	m^3/s
1966	104.2[a]	1.20	141
1967	902.8	1.83	305
1968	77.7	1.16	133
1969	248.3	1.46	167
1970	126.8	1.03	149
1971	131.5	1.31	171
1972	682.9	2.09	256
1973	42.8	0.84	94.4
1974	277.5	1.69	245
1975	1106.8	1.72	275
1976	176.9	1.31	143
1977	7.0	0.50	44.9
1978	221.9	1.36	142
1979	88.9[a]	0.96	131
1980	80.2[a]	1.05	124
1981	406.3[a]	1.54	214
1982	60.8[a]	0.95	134
1983	35.3[a]	0.78	84.6
Mean	265		
Std. dev.	315.6		

[a] Winter values estimated from mean monthly values of Table 8.

TABLE 8

ANNUAL DISTRIBUTION OF SUSPENDED SEDIMENT LOAD FOR OLDMAN RIVER NEAR BROCKET*

Month	Mean Suspended Sediment Load t/d	Number of Data	Fraction of Annual Suspended Sediment Load %
Jan.	6.01	13	0.1
Feb.	5.06	13	0.1
Mar.	127	16	1.4
Apr.	270	17	2.9
May	3950	18	44.2
June	4250	18	46.6
July	125	18	1.4
Aug.	191	18	2.2
Sept.	10.9	18	0.1
Oct.	6.24	17	0.1
Nov.	9.61	12	0.1
Dec.	15.7	12	0.2
			100.0

* WSC station 5AA24 (1966 to 1983)

TABLE 9

SUSPENDED SEDIMENT LOAD OF TRIBUTARY STREAMS

Year	Suspended Sediment Load, April through September		
	Oldman R. - Brocket kt	Oldman R. - Waldron's kt	Crowsnest R. - Frank kt
1976	73.4	39.6 (23)[a]	3.7 (2)
1977	6.2	1.3 (21)	0.6 (10)
1978	193.6	13.0 (7)	2.5 (1)
1979	86.4	7.5 (9)	3.7 (4)
1980	78.7	6.2 (8)	3.0 (3)
1981	404.5	62.9 (16)	
1982	55.6	4.0 (7)	
1983	33.4	2.2 (7)	

[a] Values in parenthesis are percentages of Oldman near Brocket load

TABLE 10

TRIBUTARY STATIONS WITH SUSPENDED SEDIMENT DATA

River	Catchment Area at Oldman R. Confluence km^2	Area at Station km^2	Ratio of Station Area to Confluence Area %
Oldman (5AA23)	2140	1450	68
Crowsnest (5AA8)	1050	401	38

TABLE 11

TRIBUTARY SUSPENDED SEDIMENT YIELDS

Catchment	Area km^2	Mean Suspended Sediment Yield t/km^2
Oldman-Brocket	4400	24
Oldman-Waldron's	1450	9.3
Crowsnest-Frank	401	6.2

TABLE 12

ALLOCATION OF SUSPENDED SEDIMENT LOAD TO TRIBUTARIES

Tributary	Percent of Total Suspended Sediment Reaching Reservoir
Upper Oldman	70
Crowsnest	10
Castle	20

TABLE 13

SIZE OF SUSPENDED SEDIMENTS

Grain Size	Percent Finer than Indicated Size						
	Year						
mm	1967	1969	1972	1974	1975	1981	Average
0.002	11	10	13	16	12	11	12
0.004	16	17	18	20	18	18	18
0.008	24	29	27	28	28	28	27
0.016	35	40	39	40	40	41	39
0.031	49	53	52	55	54	54	53
0.062	66	72	67	68	75	79	70
0.125	82	89	82	84	89	83	85
0.250	94	97	94	95	95	93	95
0.50	99	100	97	98	98	98	98
1.0	99	100	99	99	100	99	99

Notes:

- Data are for Oldman River near Brocket (5AA24)
- Annual sizes are mean of samples collected during flood events

TABLE 14

COMPOSITIONS OF OLDMAN RIVER SUSPENDED SEDIMENT

	Size Range mm	Fraction %
Clay	<0.002	10
Silt	0.002 to 0.06	60
Sand	0.06 to 2.0	30
	Total	100

Note: - From Figure 12

TABLE 15

AVERAGE GRAIN SIZE OF OLDMAN RIVER BED MATERIAL

Percent finer than	Grain Size	
	Surface mm	Sub-surface mm
90	170	120
65	120	75
50	85	58
35	55	45

TABLE 16

SIZE OF SURFACE BED MATERIAL
TRIBUTARY STREAMS*

River	Location of Sample		Grain Size		
			D_{90} mm	D_{65} mm	D_{50} mm
Oldman	Waldron's C.		189	115	86
	Cowley		216	121	80
		Average	203	118	83
Crowsnest	Frank		84	58	45
	Lundbreck		177	118	96
		Average	131	88	71
Castle	Beaver		124	69	56
	Cowley		202	113	79
		Average	163	91	68

* From Kellerhals et al 1972.

TABLE 17

ANNUAL BED MATERIAL LOAD

River	Annual Bed Load* kt/a
Upper Oldman	0.8
Crowsnest	0
Castle	1.2
Oldman at damsite	2.0

* Calculated using the bedload formulas of Ackers and White (1973), and Meyer-Peter and Muller (1948)

TABLE 18

RESERVOIR SHORELINE EROSION RATES*

Reach	Eroded Volume		
	Scenarios 1-3 m^3/a	Scenario 4 m^3/a	Scenario 5 m^3/a
Upper Oldman	11,650	8,320	5,340
Crowsnest	18,618	17,096	13,848
Castle	10,980	10,050	8,868
Oldman:			
- between Crowsnest and Castle	48,510	38,010	25,125
- downstream of Castle to dam	190,351	172,238	139,281
Totals	280,109	245,714	192,462

* From Klohn Leonoff Ltd., 1986 (Dwg. No. 2062.041)

Notes:

- Scenarios 1-3 represents conditions up to 20 years after dam completion
- Scenario 4 represents conditions 21 to 30 years after dam completion
- Scenario 5 represents conditions 31 years and more after dam completion

TABLE 19

TOTAL SEDIMENT DEPOSITION IN OLDMAN RESERVOIR

Reservoir Reach	50-Year Sediment Deposition			
	River-Borne Volume	Shore-Erosion Volume	Total Volume	Fraction of Total
	hm^3	hm^3	hm^3	%
Upper Oldman	1.9	0.4	2.3	8
Crowsnest	0.3	0.8	1.1	4
Castle	1.7	0.5	2.2	8
Oldman				
- between Crowsnest and Castle	4.5	1.9	6.4	23
- downstream of Castle to Dam	7.6	8.3	15.9	57
Totals	16.0	11.9	27.9	100

TABLE 20*

EFFECT OF POSSIBLE RESERVOIR CROSSING STRUCTURES ON FLOW AREAS

River	Crossing Designation	Flow Area Below El. 1118.6 m (FSL)		Ratio of Areas
		Without Crossing	With Crossing	
		m^2	m^2	%
Upper Oldman	B	915	847	93
Upper Oldman	H	5320	4640	87
Crowsnest	I	1110	1110	100
Crowsnest	J	5630	2410	43

* See Figure 17 for crossing locations

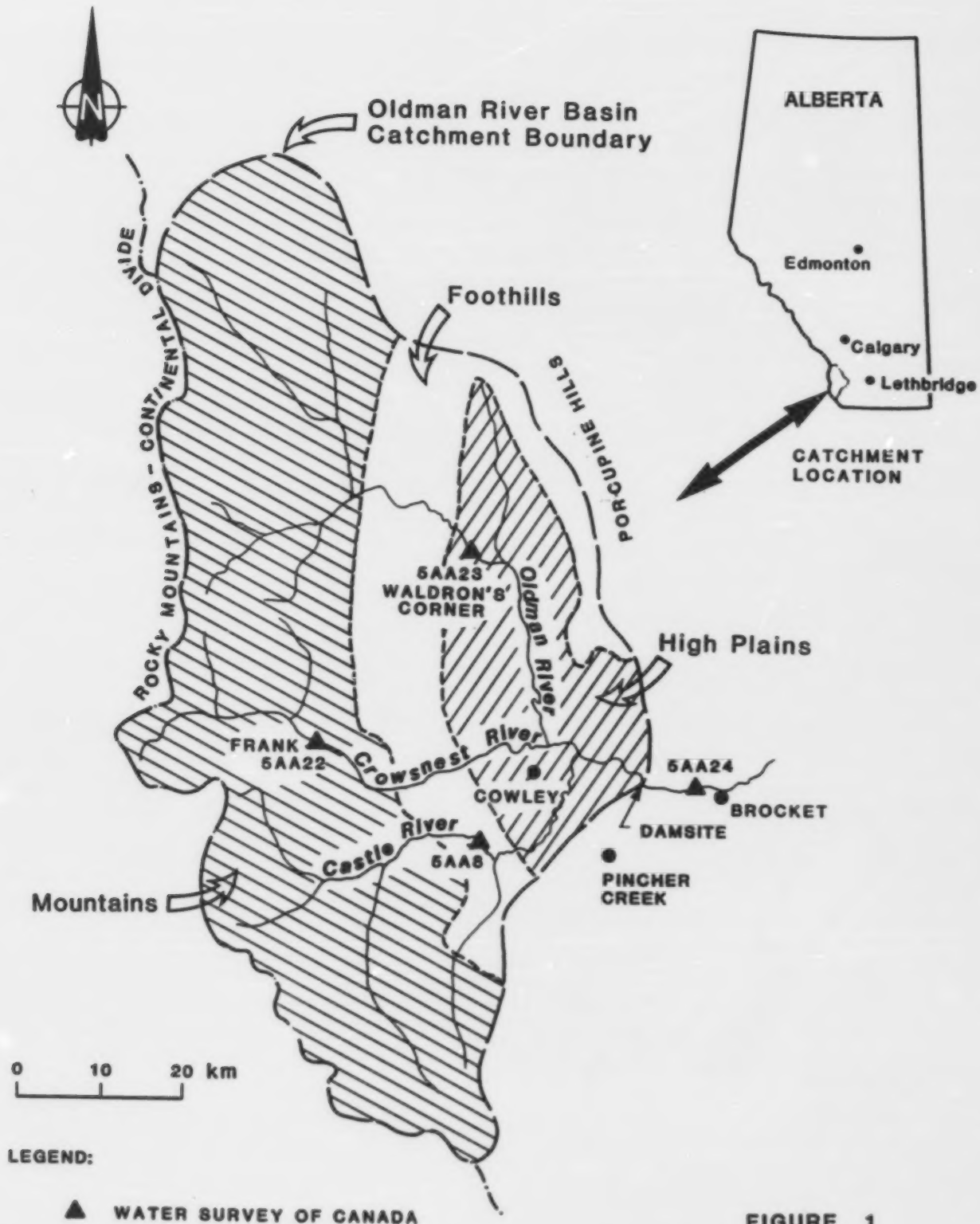


FIGURE 1

MAP OF CATCHMENT

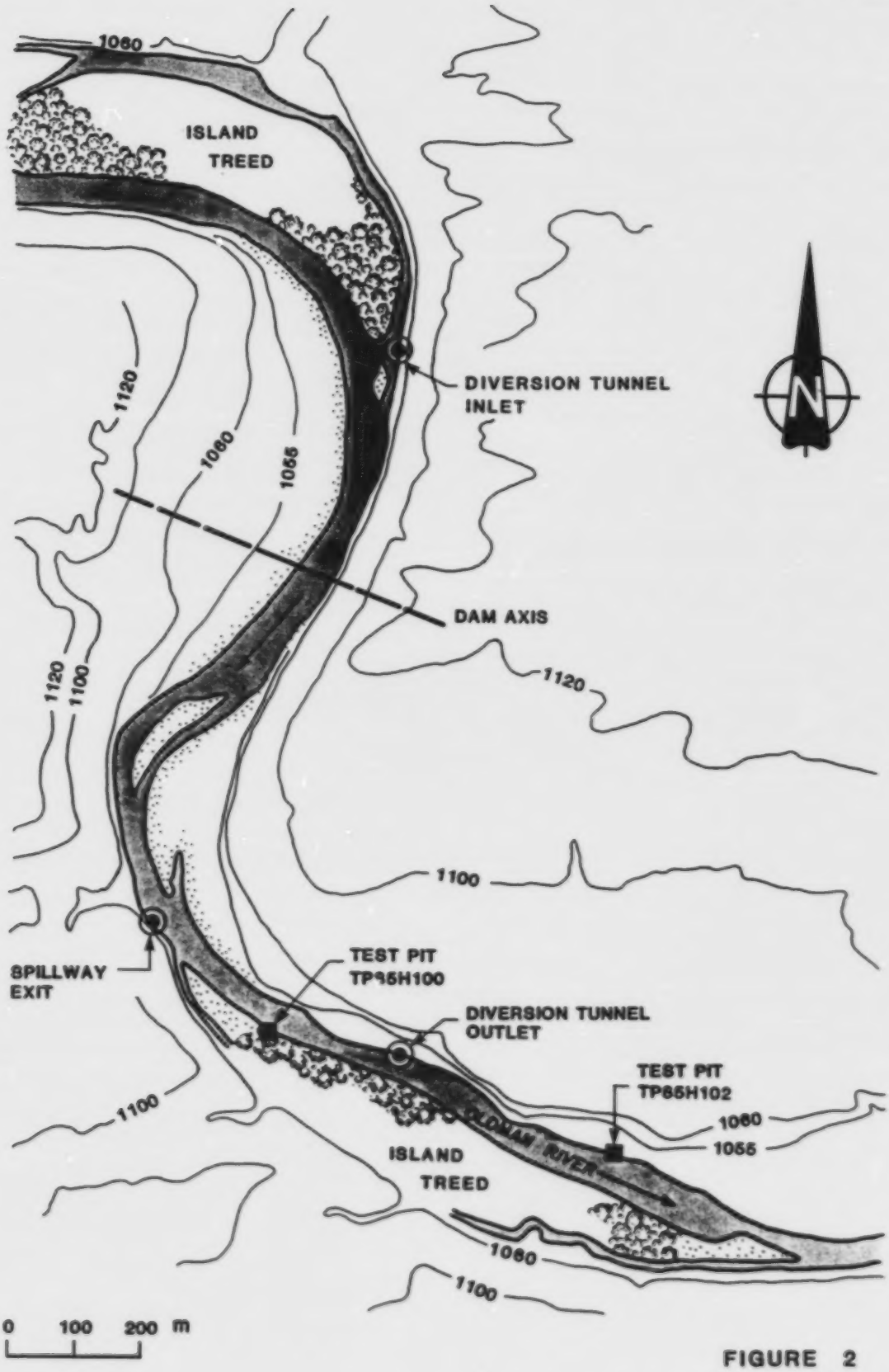
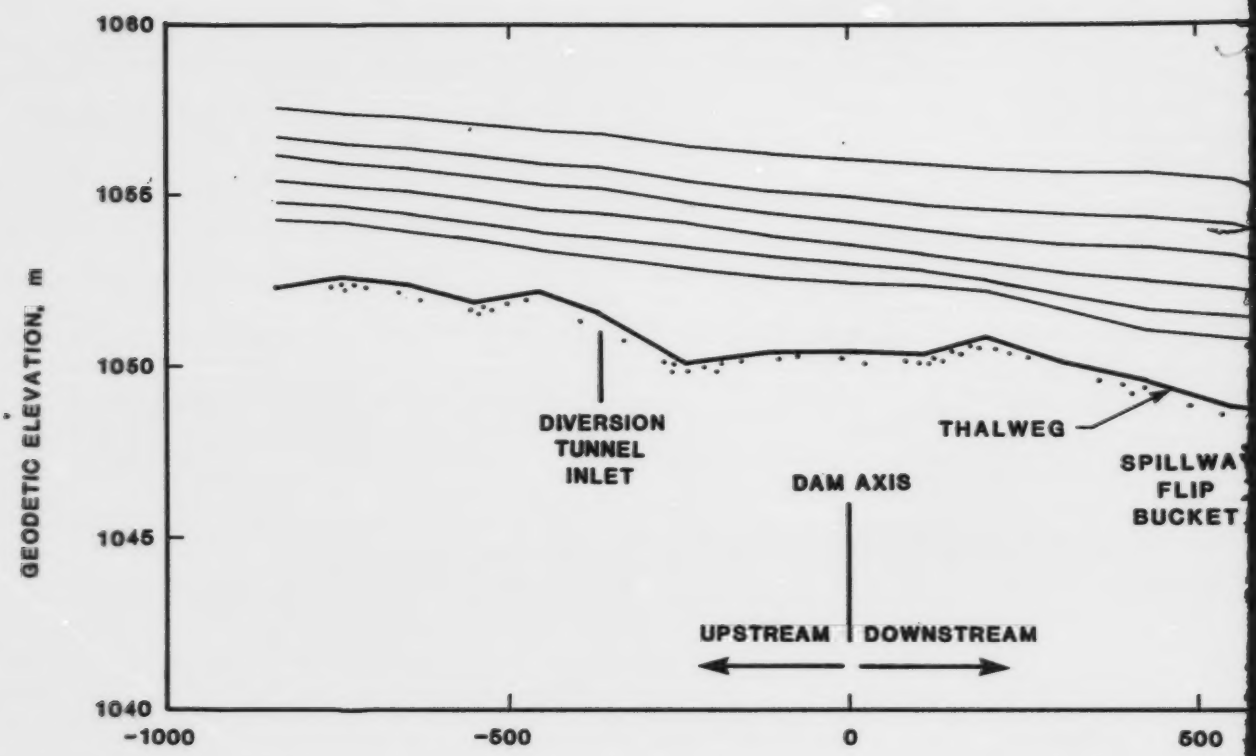


FIGURE 2

MAP OF DAMSITE



NOTE:

- WATER LEVELS ARE CALCULATED

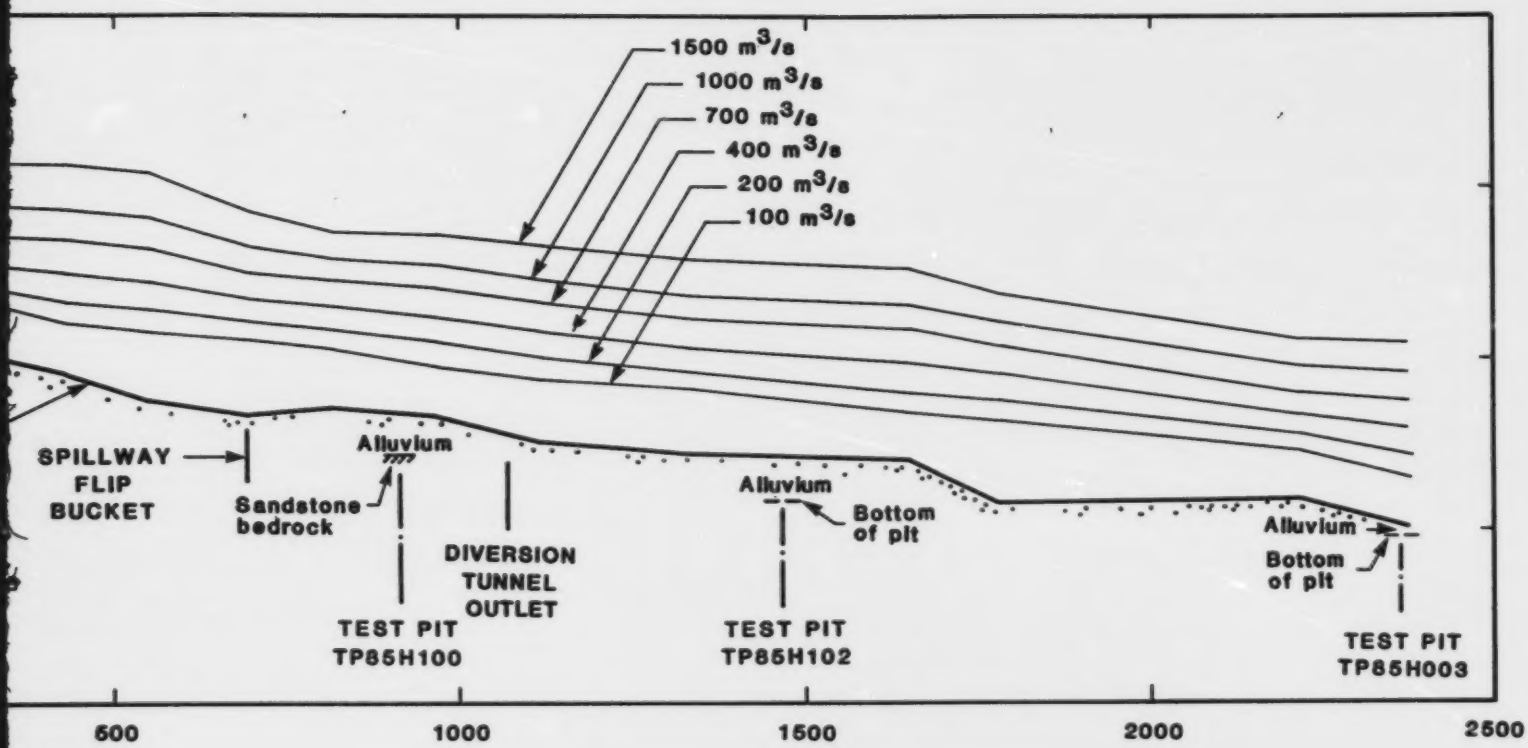
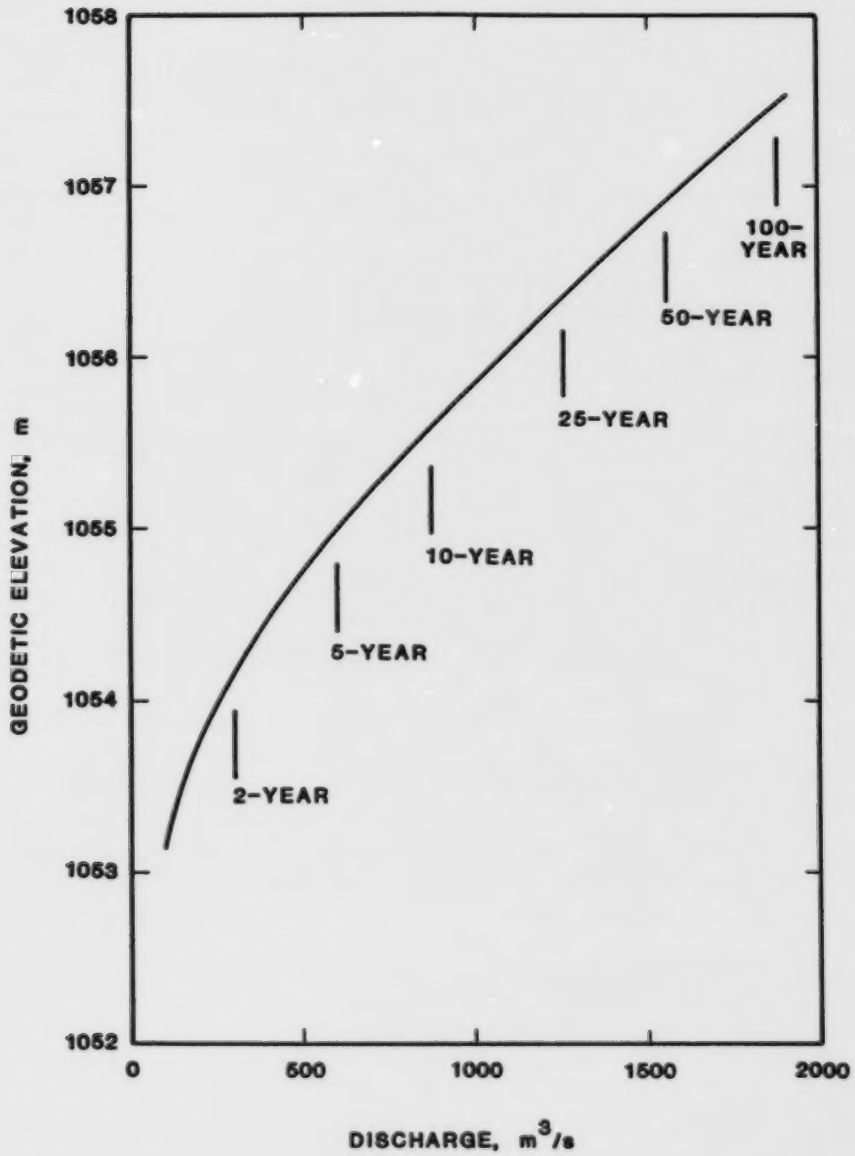


FIGURE 3

OLDMAN RIVER PROFILE
AT DAMSITE

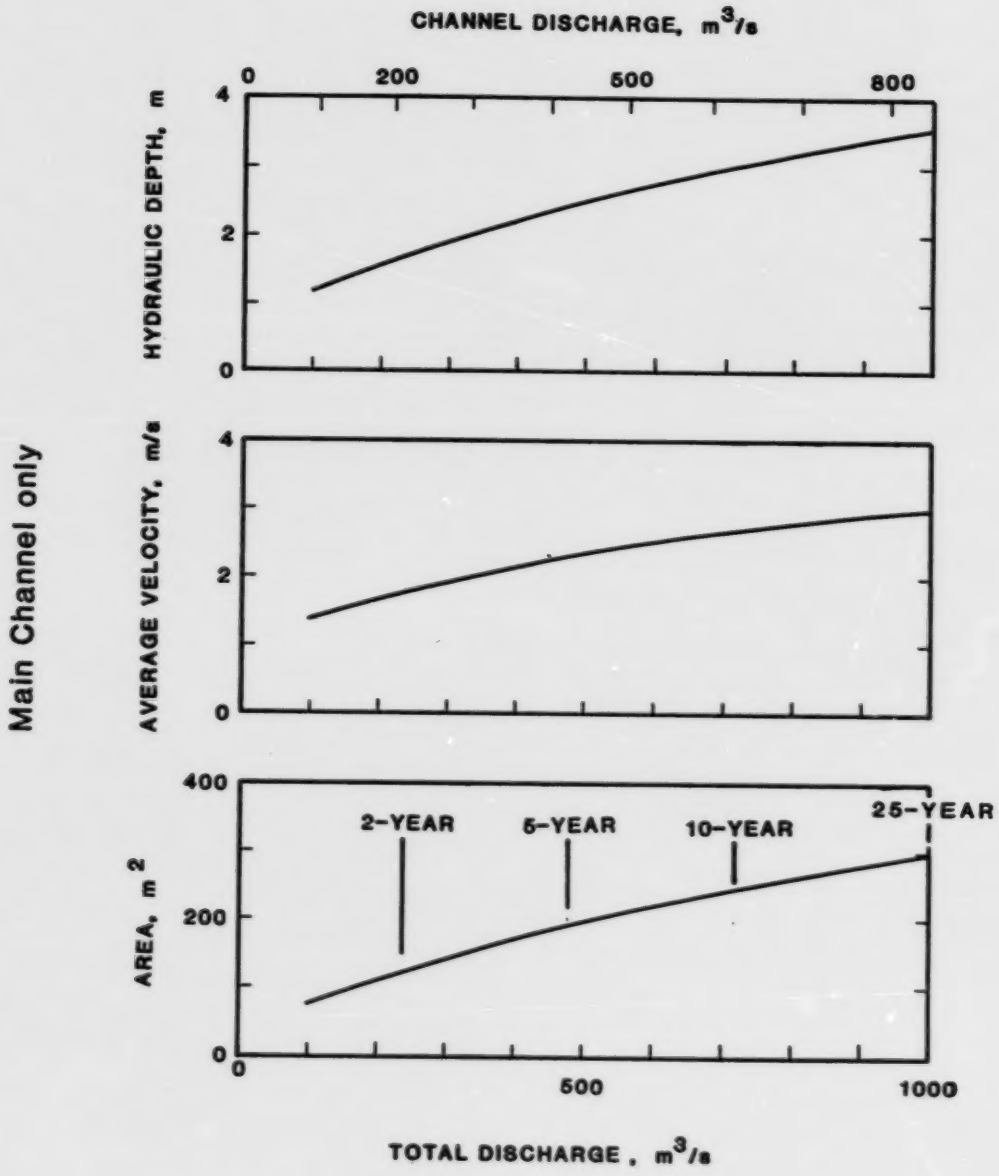


NOTES:

- SEE FIGURE 2 FOR LOCATION
- FLOOD DISCHARGES ARE INSTANTANEOUS VALUES

FIGURE 4

DISCHARGE RATING CURVE
AT DIVERSION TUNNEL INLET



NOTES:

- FLOOD FLOWS ARE MAXIMUM DAILY.
- PROPERTIES ARE FOR A 1 km REACH OF THE CHANNEL BETWEEN 400 m AND 1400 mm DOWNSTREAM OF THE DAM SITE.

FIGURE 5

HYDRAULIC GEOMETRY OF OLDMAN RIVER CHANNEL BELOW DAMSITE

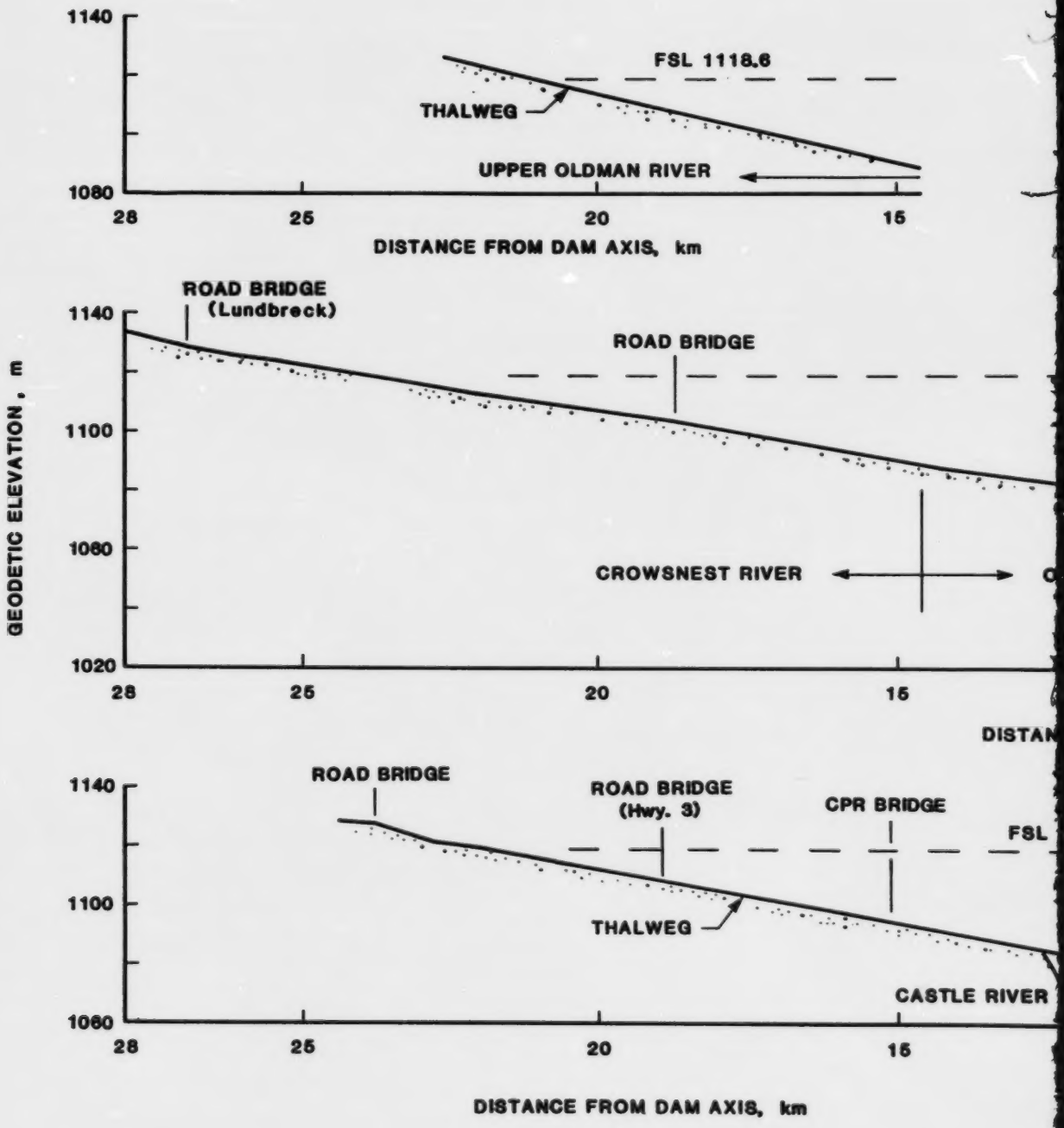

1140
1080
FSL 1118.6
THALWEG
UPPER OLDMAN RIVER
28
25
20
15
DISTANCE FROM DAM AXIS, km
ROAD BRIDGE
(Lundbreck)
ROAD BRIDGE
1140
1100
1080
1020
GEODETIC ELEVATION, m
CROWSNEST RIVER
28
25
20
15
DISTAN
ROAD BRIDGE
ROAD BRIDGE
(Hwy. 3)
CPR BRIDGE
FSL
1140
1100
1060
THALWEG
CASTLE RIVER
28
25
20
15
DISTANCE FROM DAM AXIS, km

TABLE OF
AVERAGE RIVER SLOPES

River	Reach km	Slope m/km
Upper Oldman	22-15	4.7
Crowsnest	25-15	3.2
Castle	22-10	3.6
Oldman:		
U/S of Dam	14-0	2.6
D/S of Dam	0-7	2.2

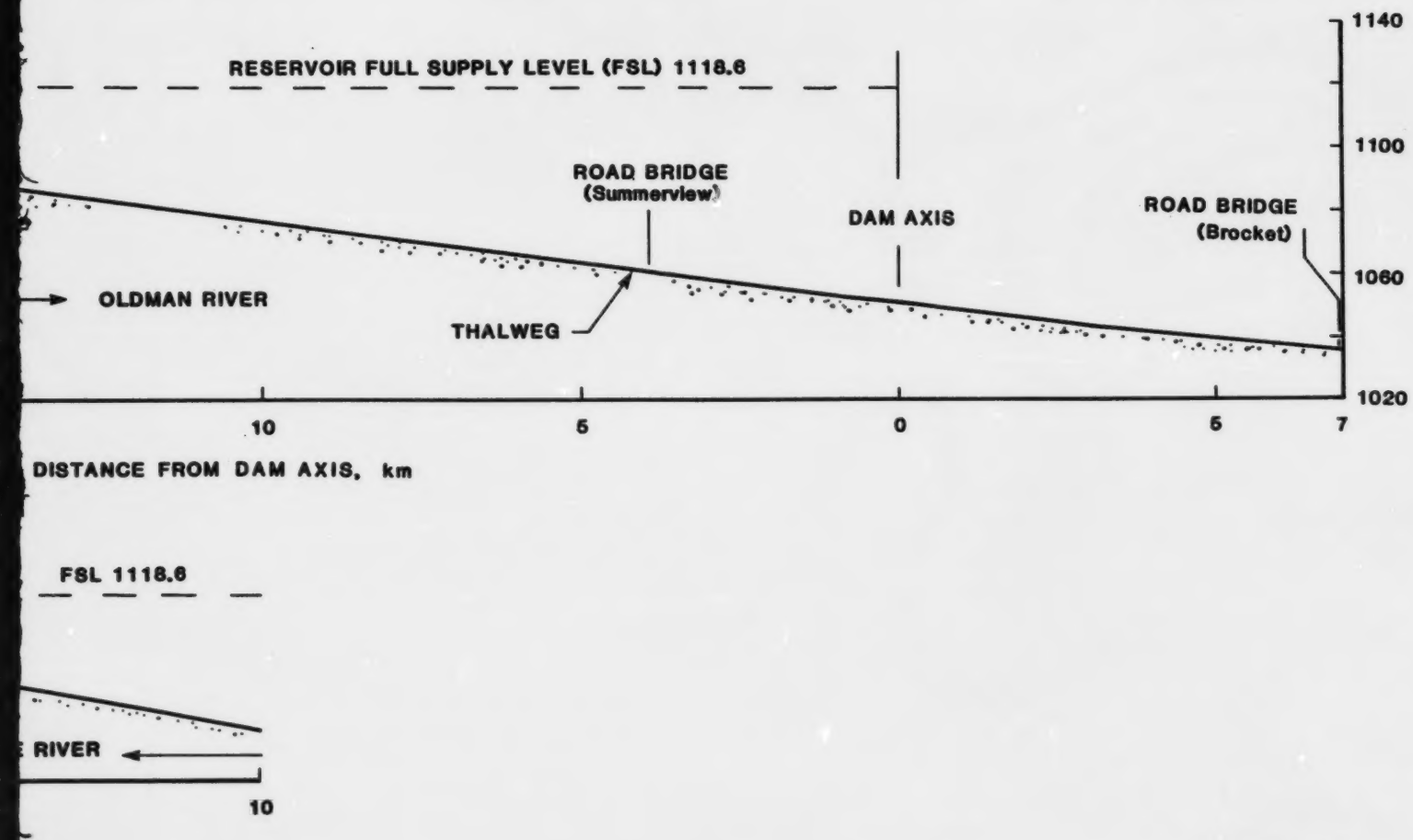
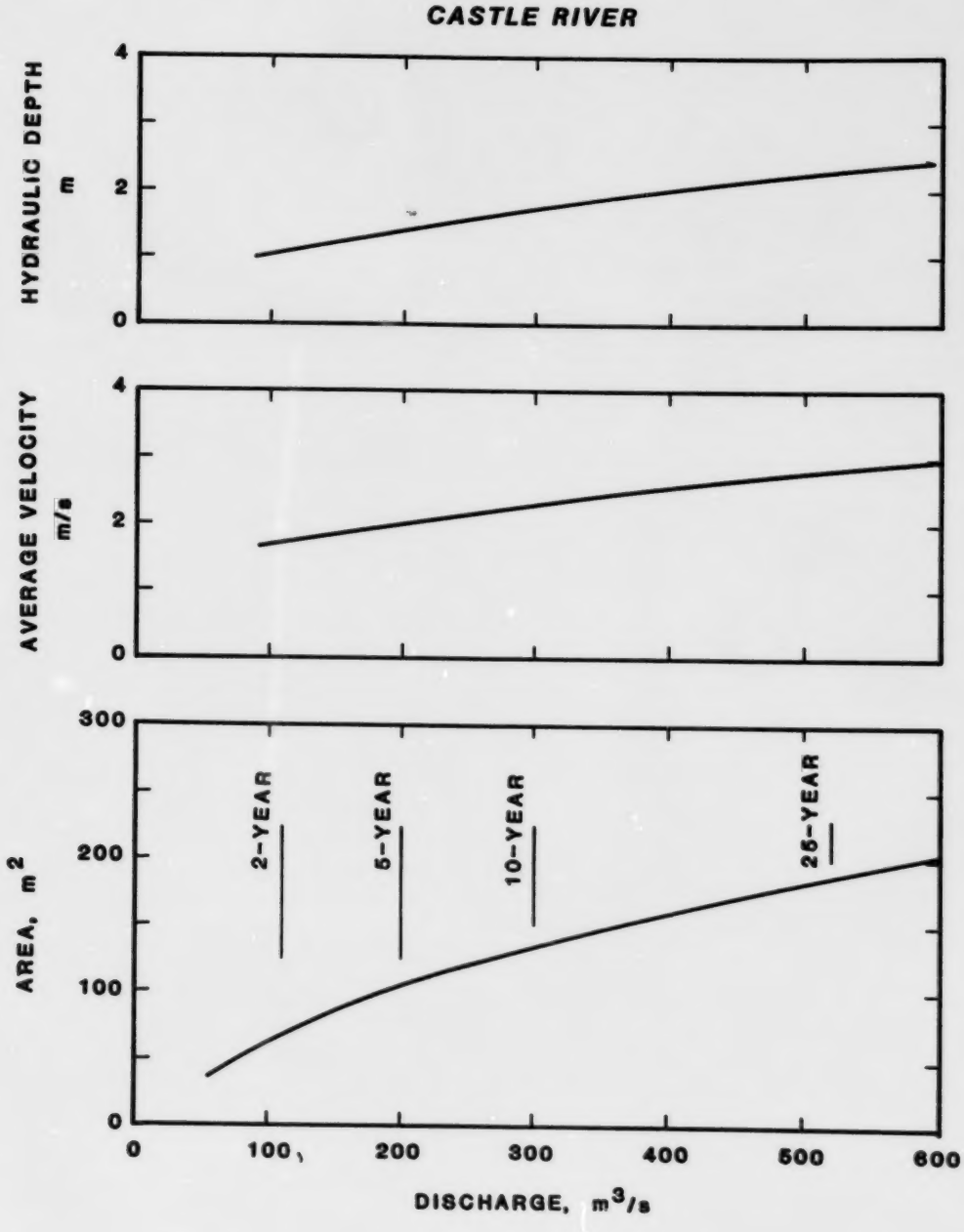


FIGURE 6

THALWEG PROFILES OF
MAJOR TRIBUTARIES



NOTES:

- FLOOD FLOWS ARE APPROXIMATE MAXIMUM DAILY.
- HYDRAULIC PROPERTIES ARE FOR THE FOLLOWING REACHES (REFER TO FIGURE 6):
  - CASTLE RIVER, km 20 TO km 24.
  - UPPER OLDMAN RIVER, km 18 TO km 23.
  - CROWSNEST RIVER, km 16 TO km 27.

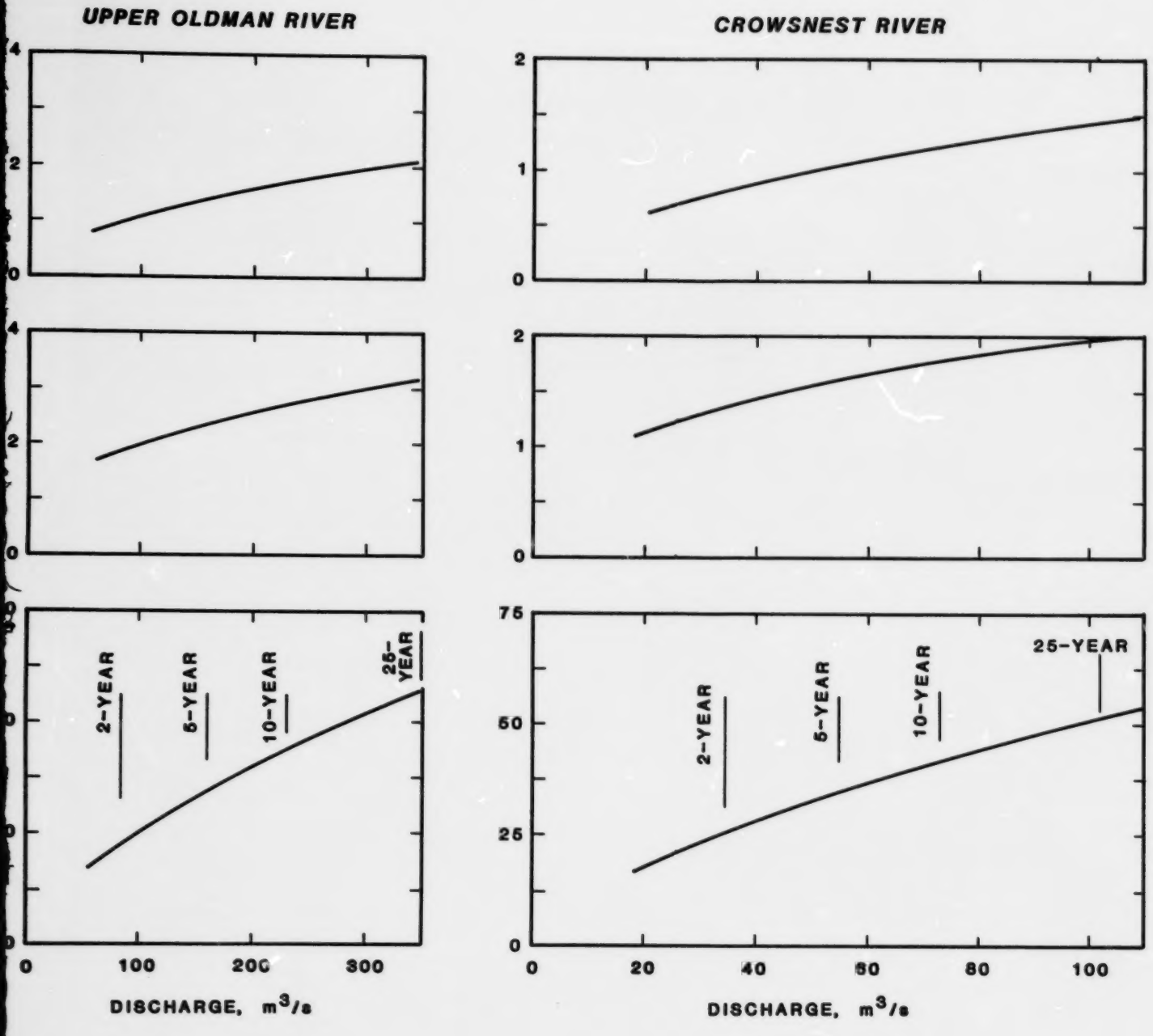
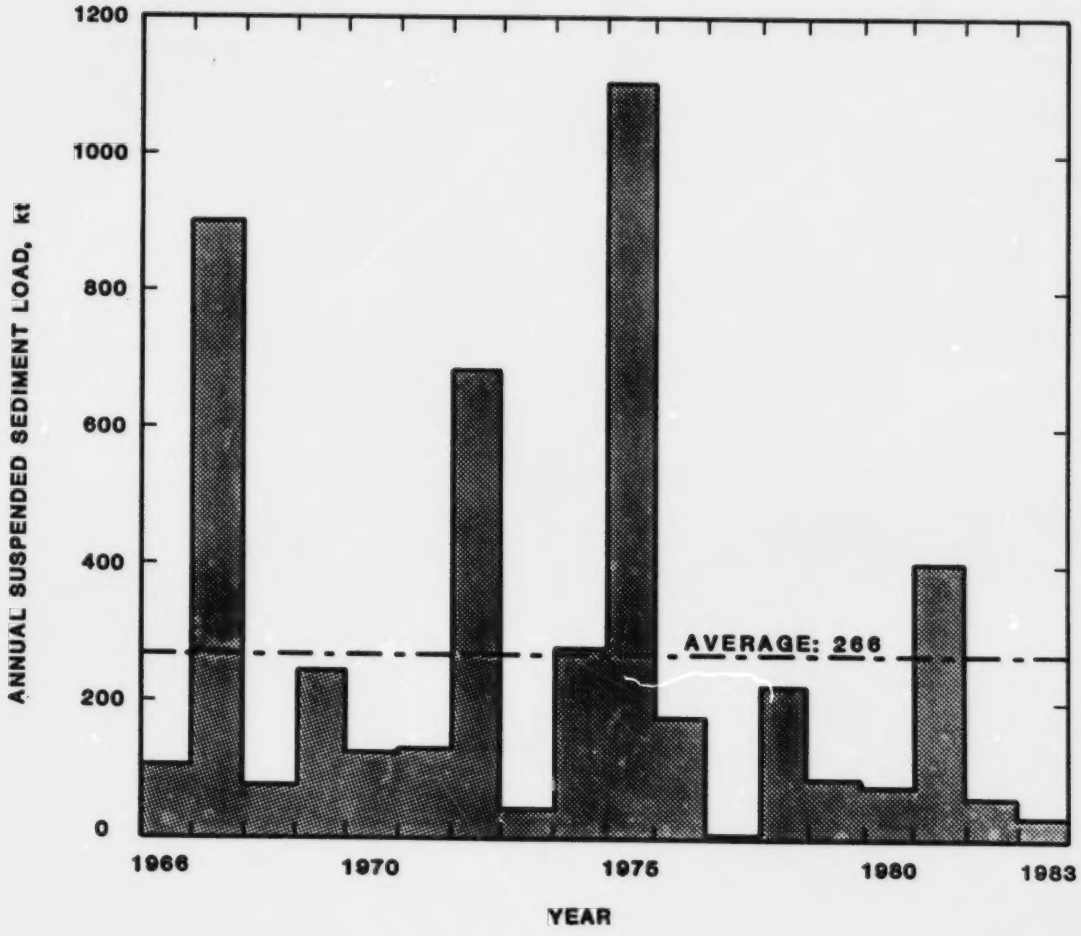


FIGURE 7

HYDRAULIC GEOMETRY
OF TRIBUTARY CHANNELS

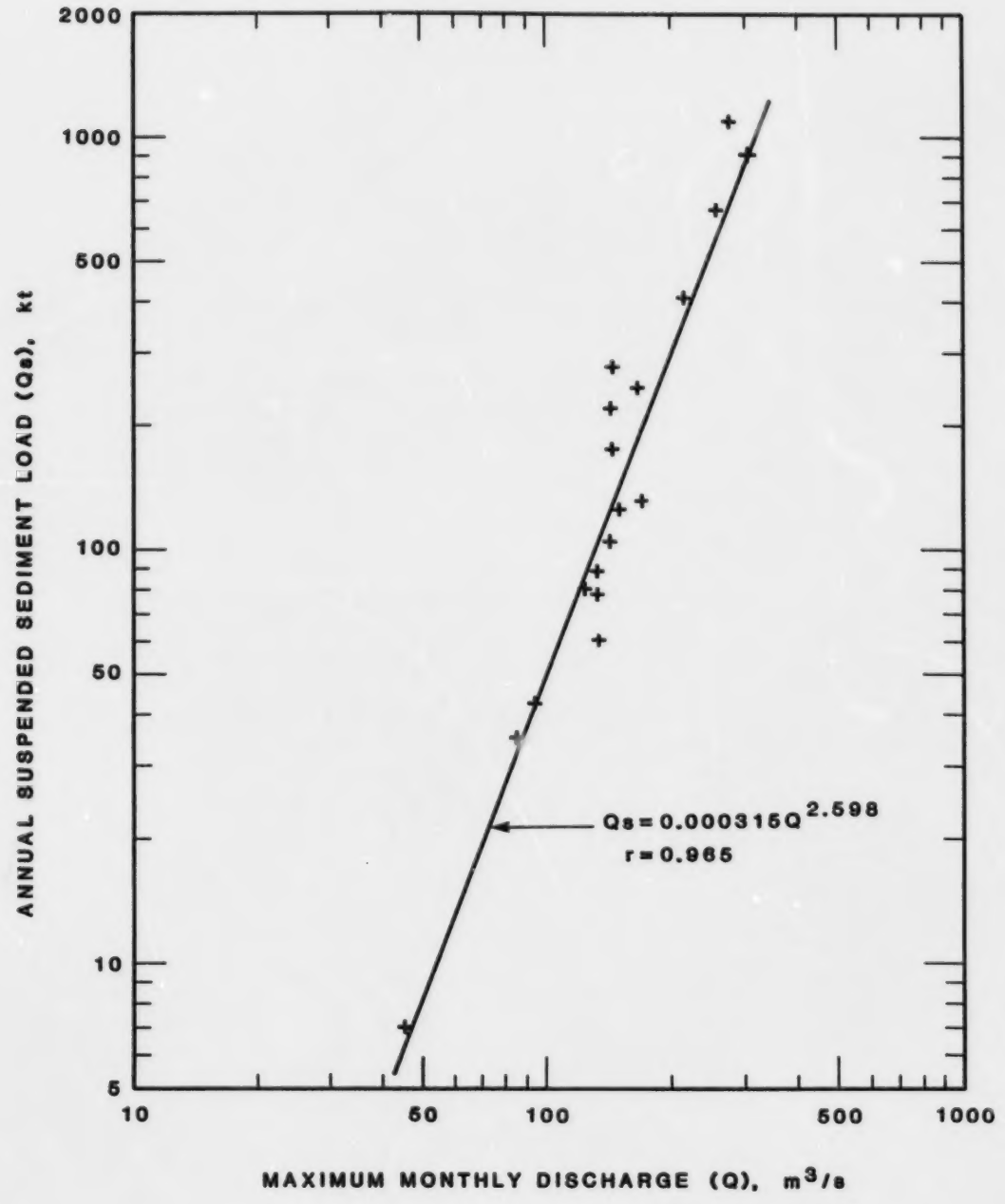


NOTE:

- DATA FOR WSC STATION 5AA24, OLDMAN RIVER NEAR BROCKET

FIGURE 8

ANNUAL SUSPENDED SEDIMENT LOADS (1966 - 1983)

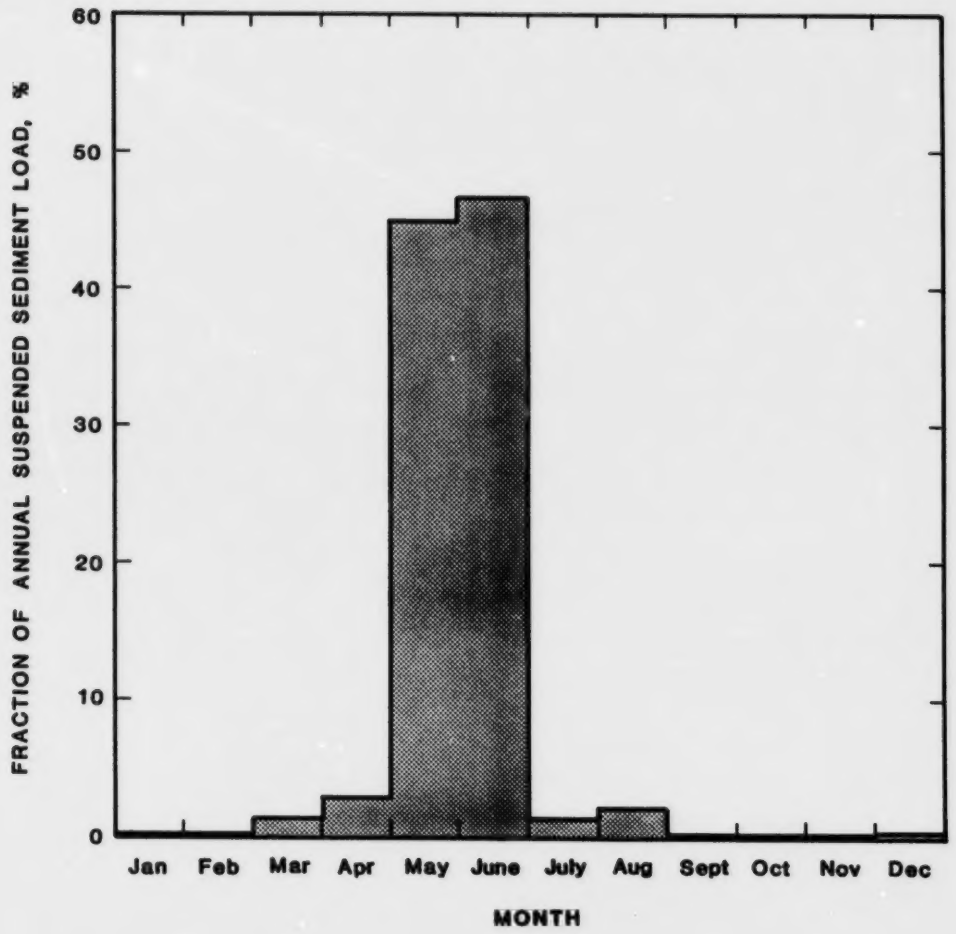


NOTE:

- DATA FOR WSC STATION 5AA24, OLDMAN RIVER NEAR BROCKET (1966 to 1983).

FIGURE 9

ANNUAL SUSPENDED SEDIMENT LOAD
vs. MAXIMUM MONTHLY DISCHARGE

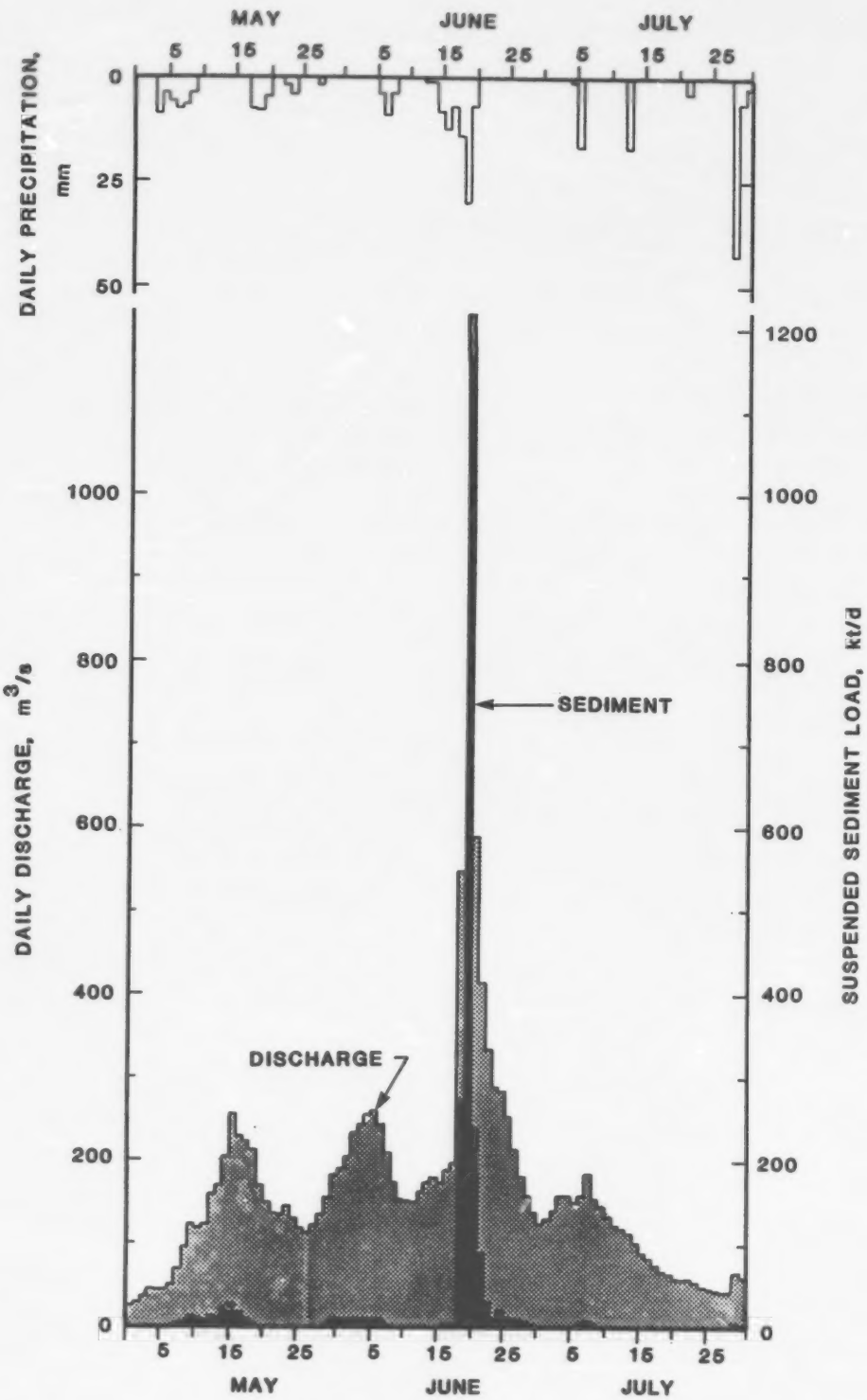


NOTE:

- DATA FOR WSC STATION 5AA24, OLDMAN RIVER NEAR BROCKET

FIGURE 10

ANNUAL DISTRIBUTION OF SUSPENDED SEDIMENT LOAD

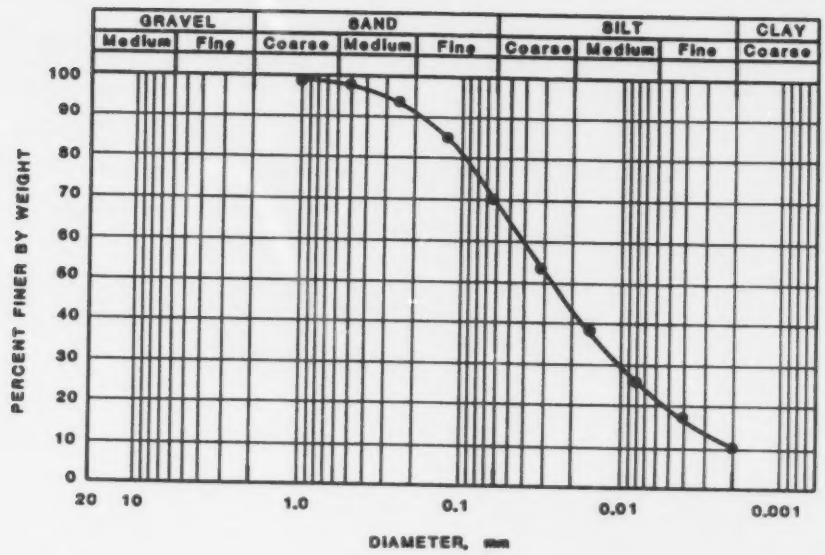


NOTES:

- DISCHARGE AND SEDIMENT DATA ARE FOR WSC STATION 5AA24, OLDMAN RIVER (Brocket).
- PRECIPITATION DATA IS MEAN OF COWLEY, COWLEY OLIN AND PINCHER CREEK.

FIGURE 11

DISCHARGE AND SUSPENDED SEDIMENT HYDROGRAPH FOR 1975

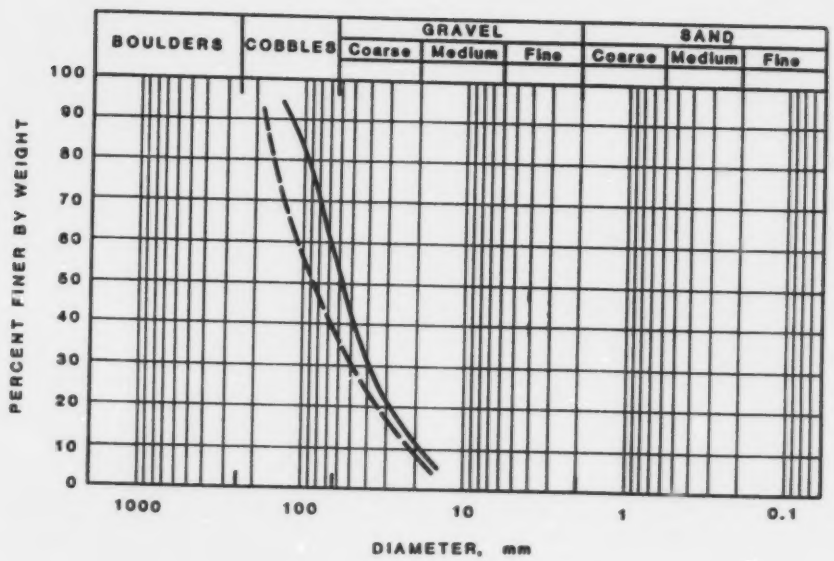


NOTE:

- DATA ARE AVERAGE VALUES FROM TABLE 13.

FIGURE 12

GRAIN SIZE DISTRIBUTION CURVE OF
OLDMAN RIVER SUSPENDED SEDIMENT



LEGEND:

——— SURFACE

——— SUB-SURFACE

NOTES:

- FOR REACH OF OLDMAN RIVER BELOW DAMSITE.
- SEE APPENDIX C FOR DETAILS.

FIGURE 13

GRAIN SIZE DISTRIBUTION CURVES
OF OLDMAN RIVER BED MATERIAL

TABLE OF
RESERVOIR AREA AND CAPACITY*

Reach	Area km^2	Volume hm^3
A	13.4	344
B	2.5	52
C	4.2	55
D	1.6	19
E	2.6	30
Totals	24.3	500

*At full supply level of 1118.6m

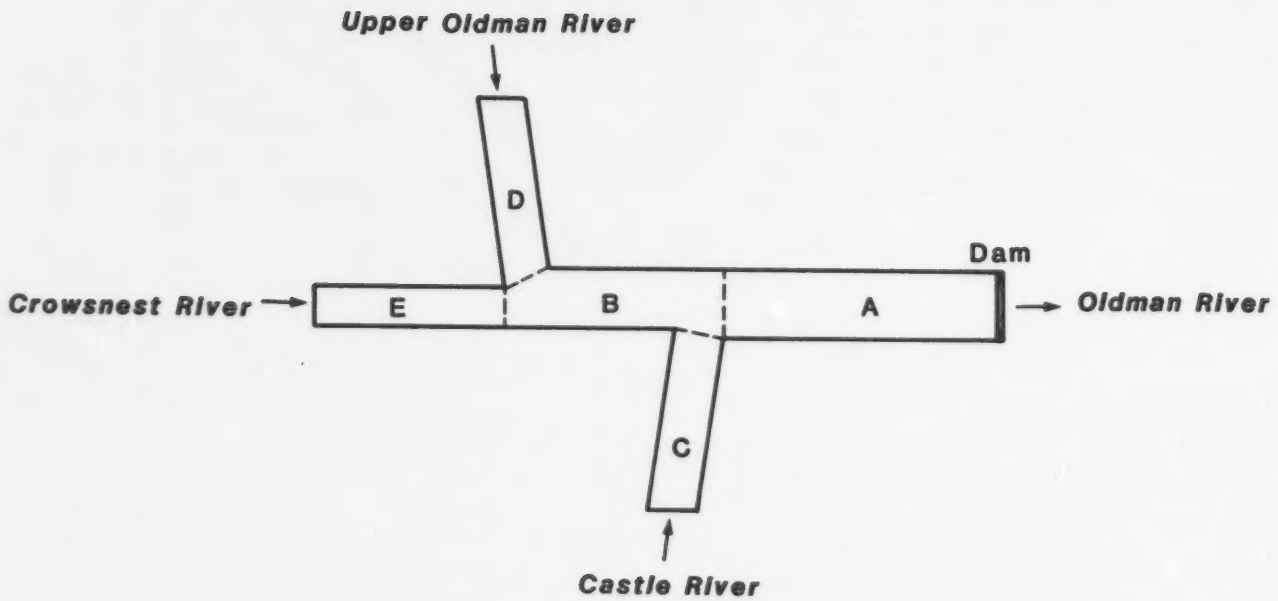


FIGURE 14

SCHEMATIC OF RESERVOIR

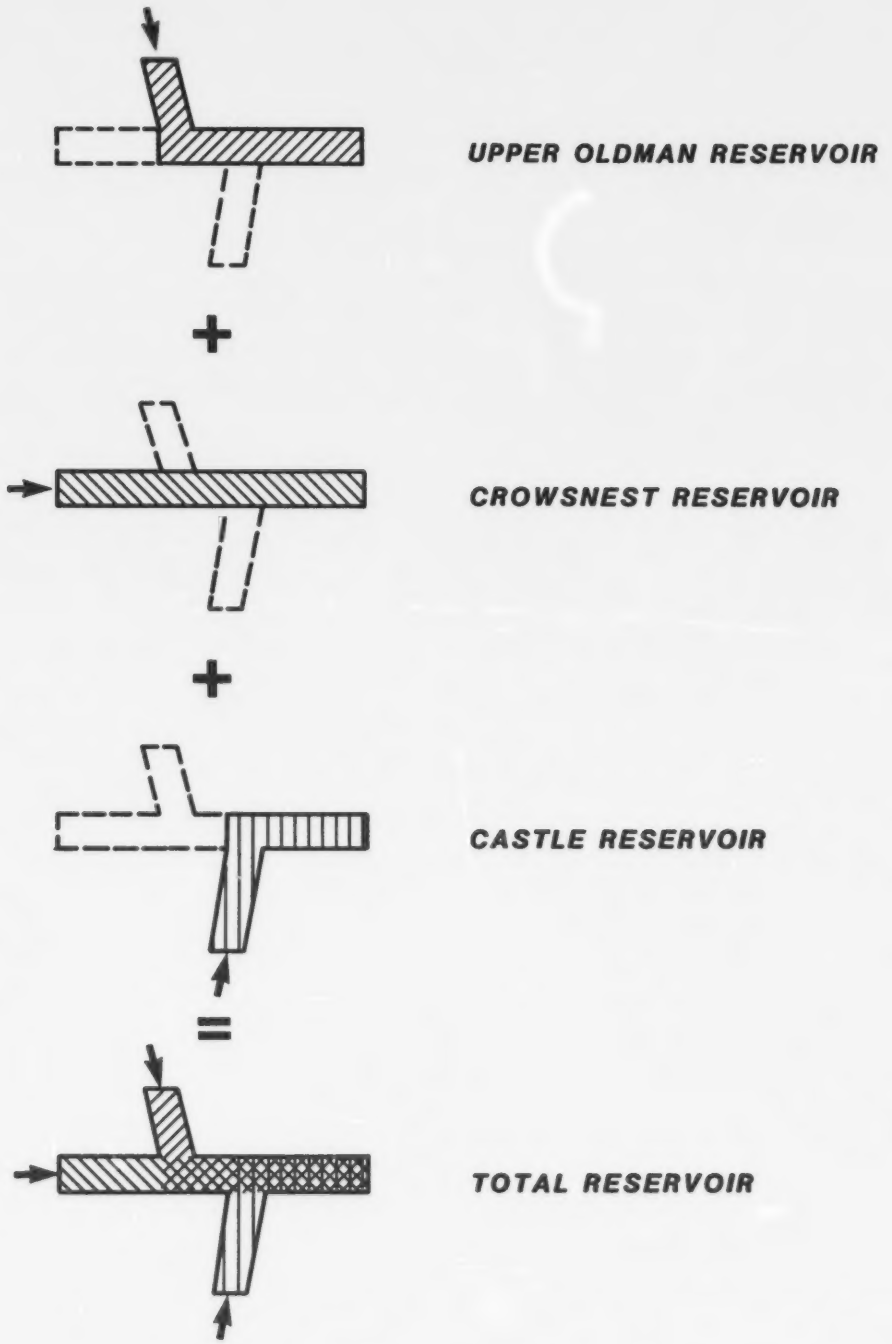
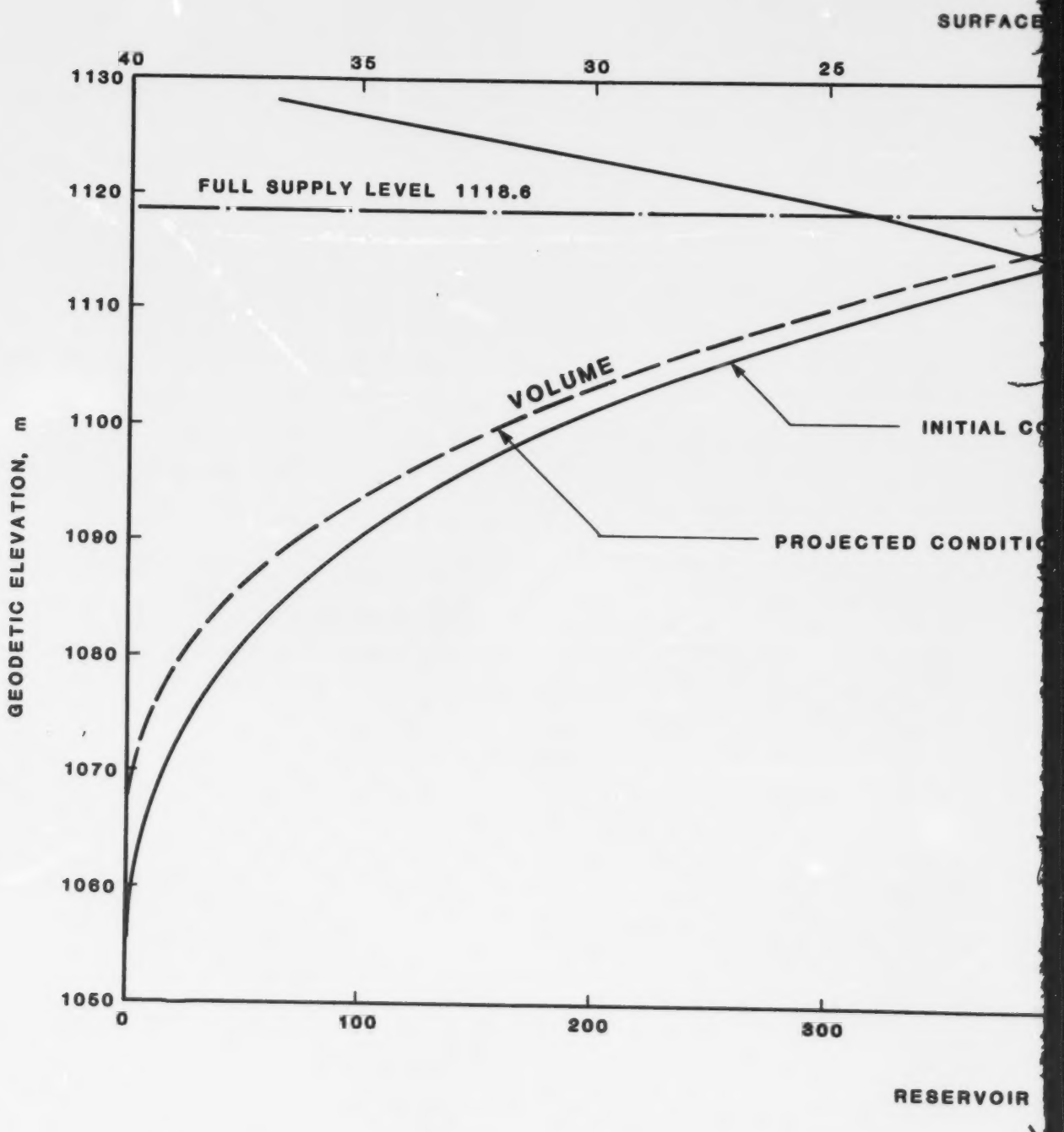


FIGURE 15

RESERVOIR SEDIMENTATION PROCEDURE


SURFACE
40
35
30
25
1130
1120
1110
1100
1090
1080
1070
1060
1050
FULL SUPPLY LEVEL 1118.6
VOLUME
INITIAL C
PROJECTED CONDITI
GEODETIC ELEVATION, m
0
100
200
300
RESERVOIR

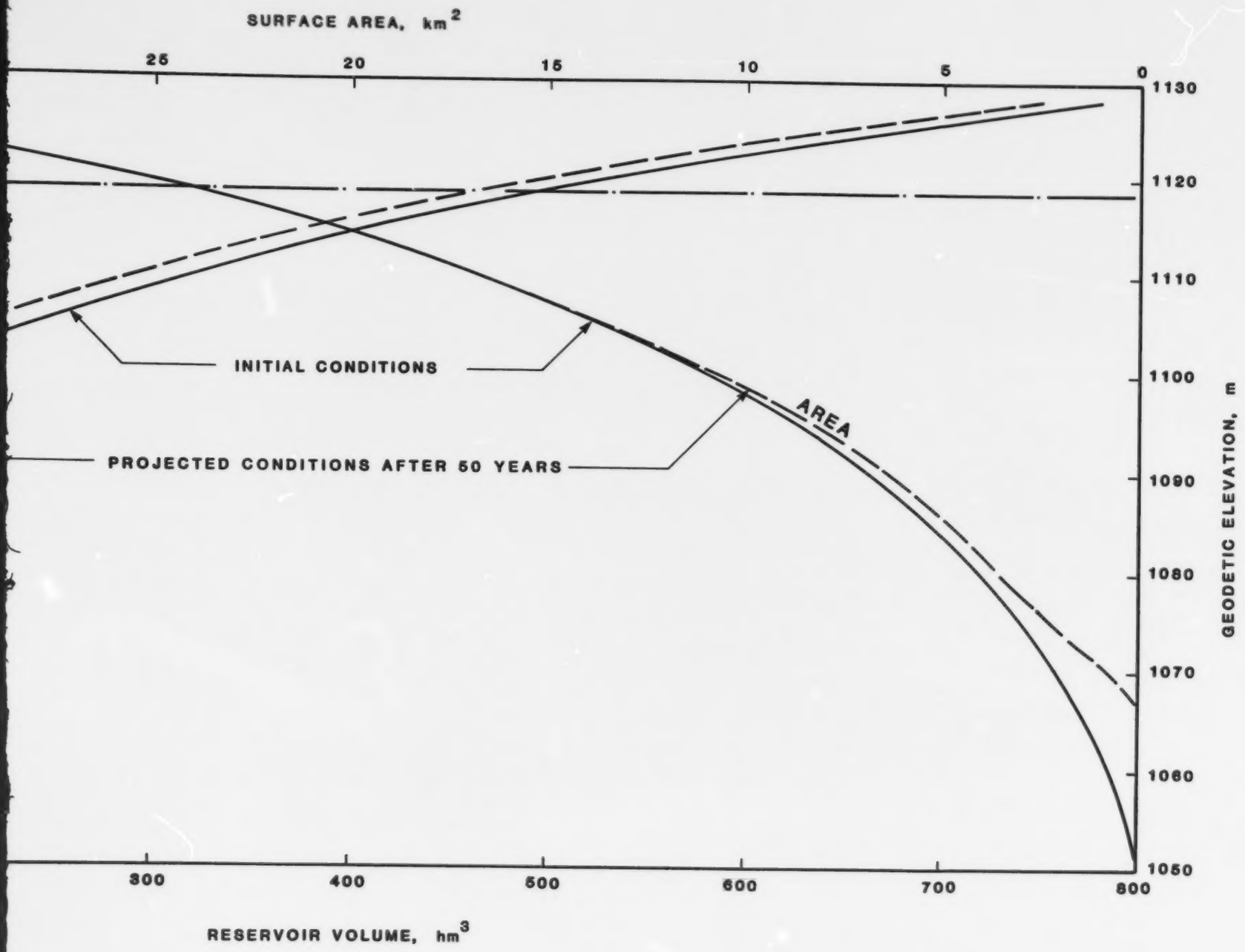
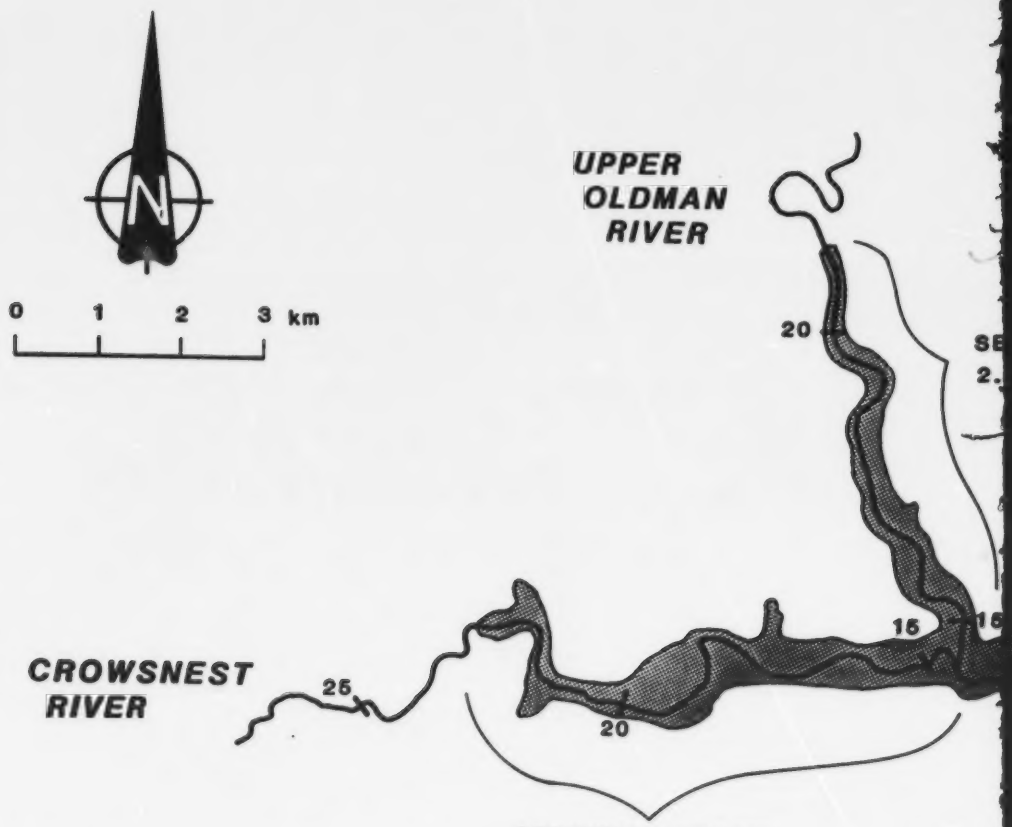


FIGURE 16

RESERVOIR CAPACITY
AND AREA CURVES



LEGEND:

15 — DISTANCE UPSTREAM OF DAM AXIS (km)

NOTE:

- SEDIMENT DEPOSITION VOLUMES ARE FOR 50 YEARS.

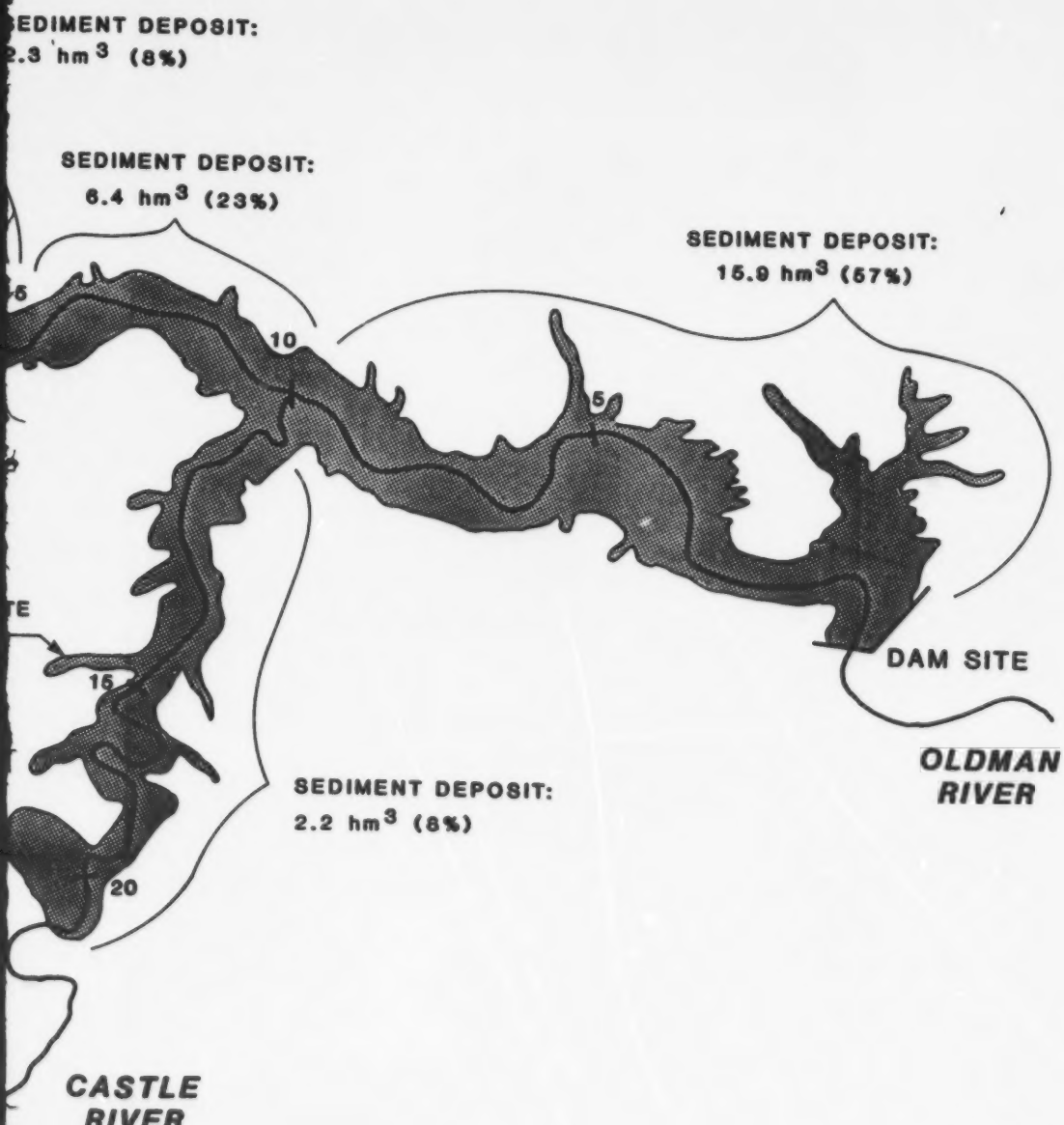
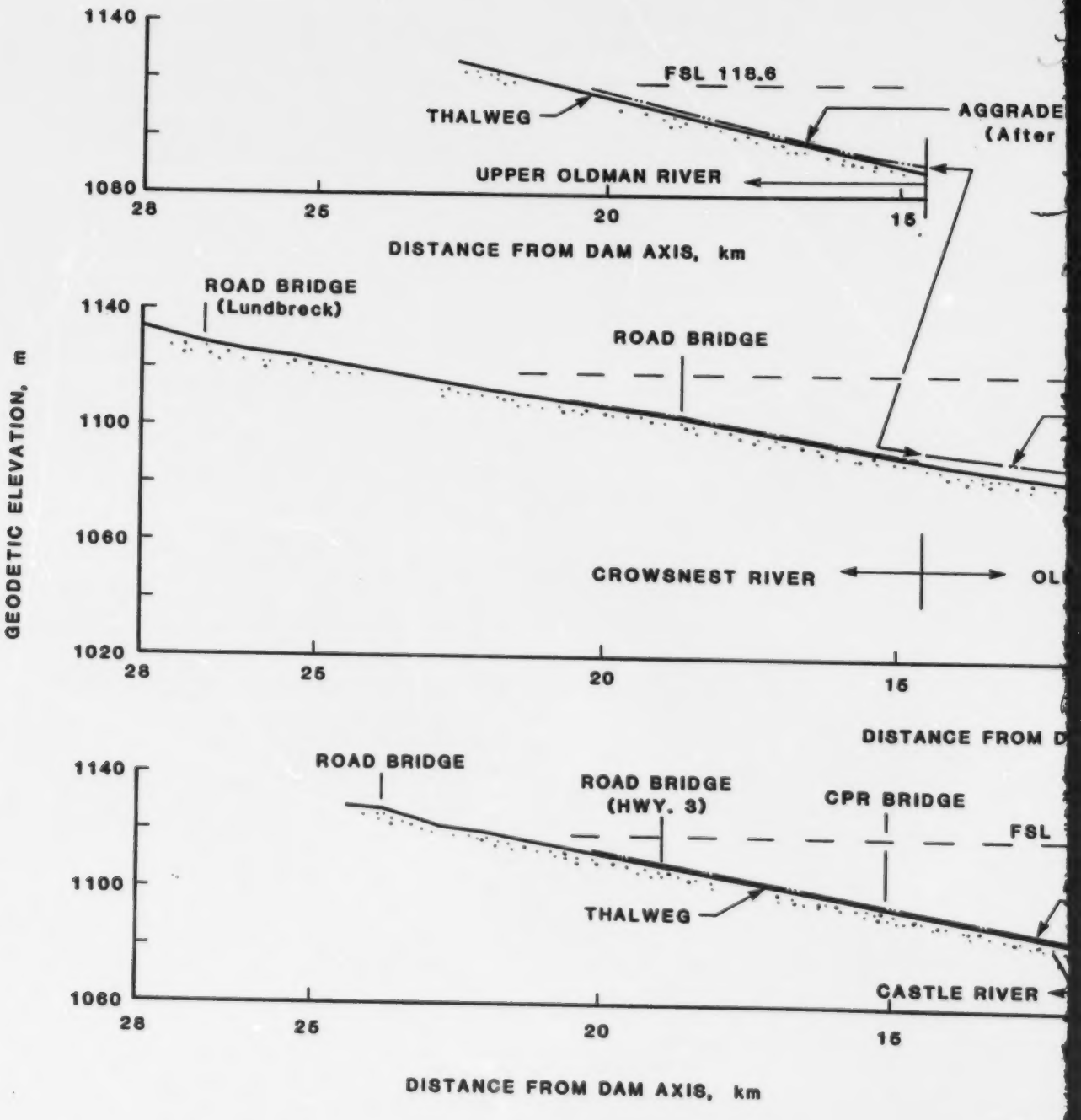


FIGURE 17

PLAN OF RESERVOIR
SHOWING PROJECTED
SEDIMENT DEPOSITION


1140
1080
FSL 118.6
THALWEG
AGGRADE
(After
UPPER OLDMAN RIVER
28
25
20
15
DISTANCE FROM DAM AXIS, km
ROAD BRIDGE
(Lundbreck)
1140
ROAD BRIDGE
1100
1060
CROWSNEST RIVER
OL
1020
28
25
20
15
GEODETIC ELEVATION, m
DISTANCE FROM D
ROAD BRIDGE
ROAD BRIDGE
(HWY. 3)
CPR BRIDGE
1140
FSL
1100
THALWEG
1060
CASTLE RIVER
28
25
20
15
DISTANCE FROM DAM AXIS, km

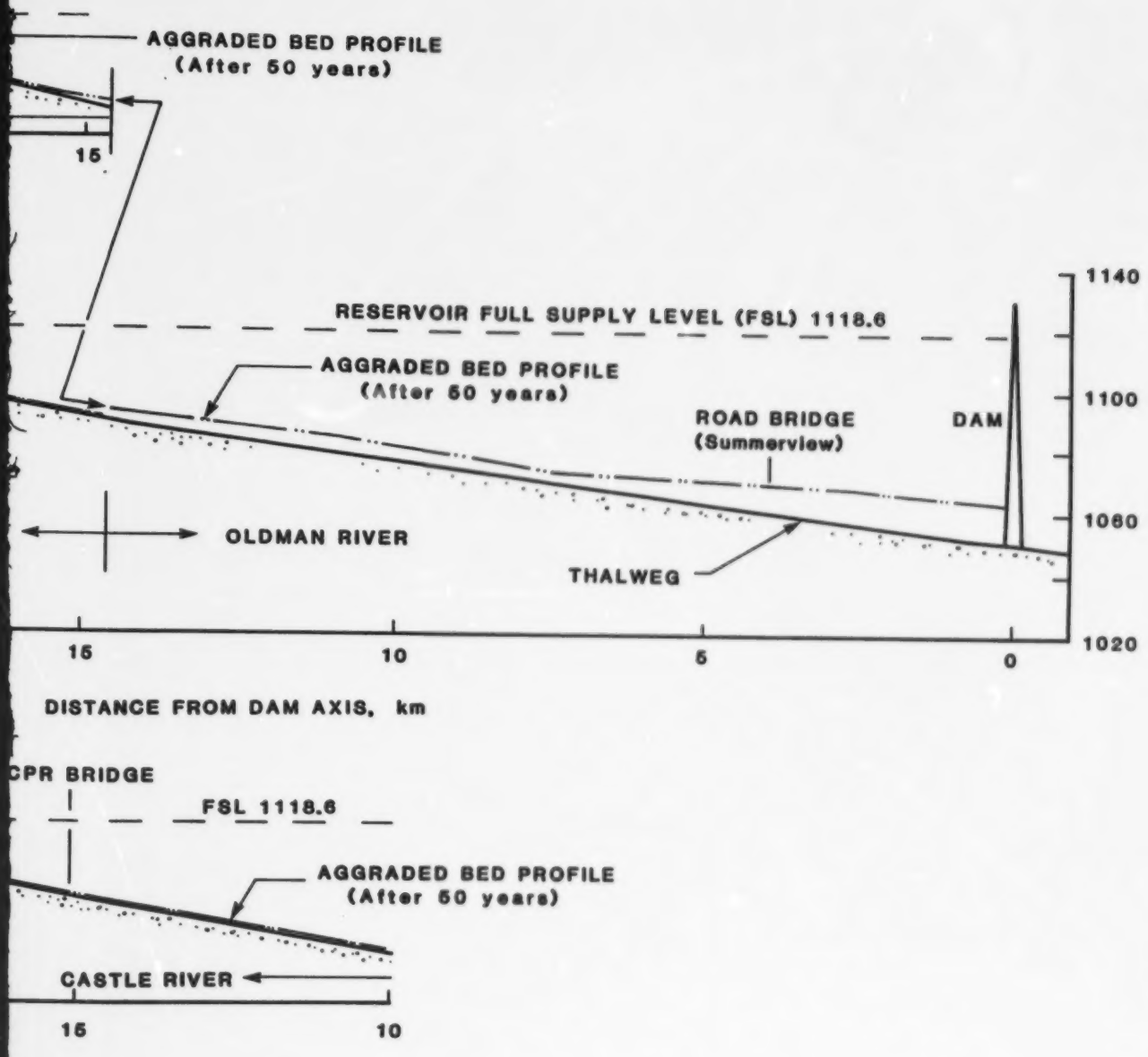
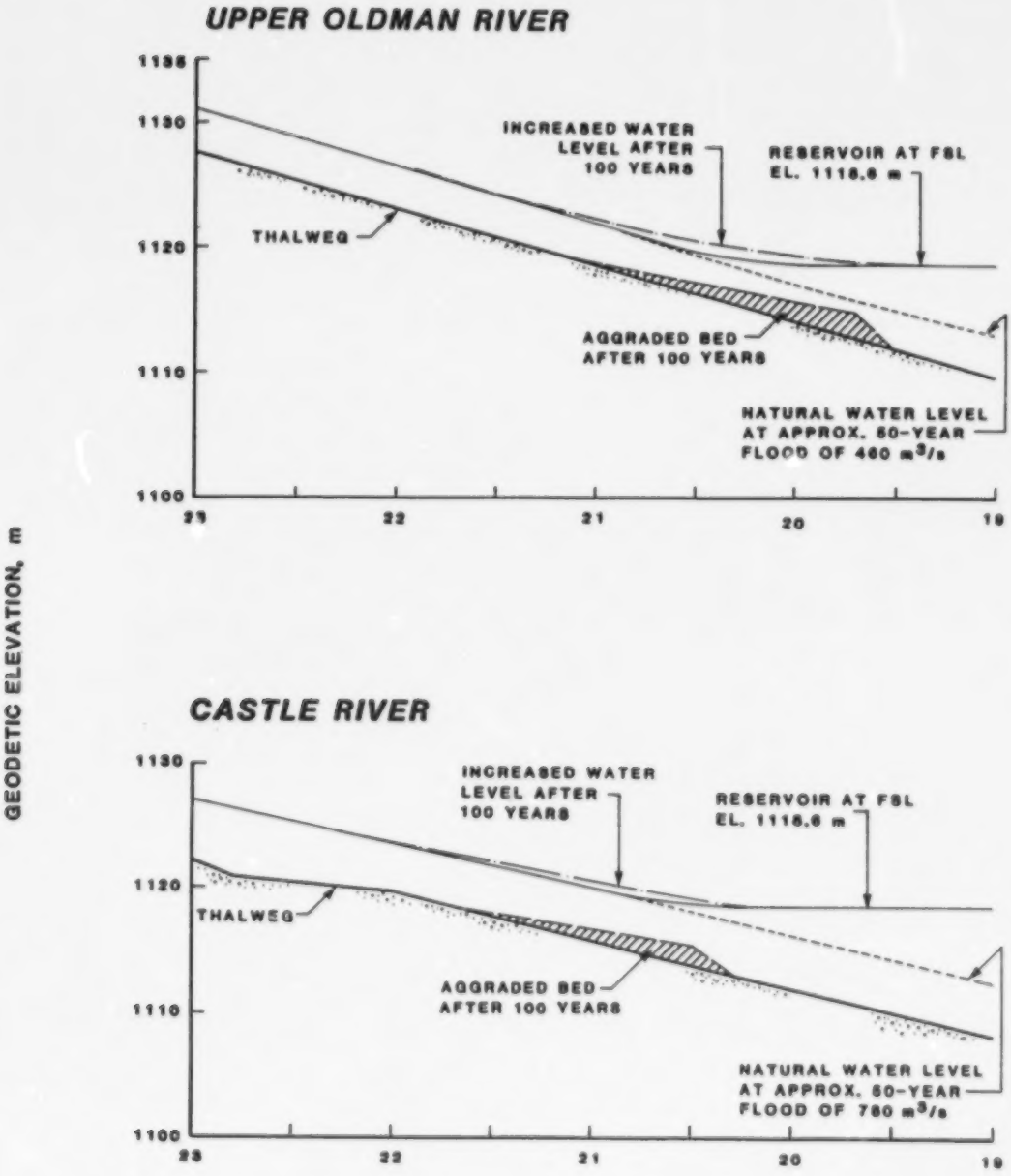


FIGURE 18

DEPOSITION THICKNESS OF SEDIMENTS AFTER 50 YEARS

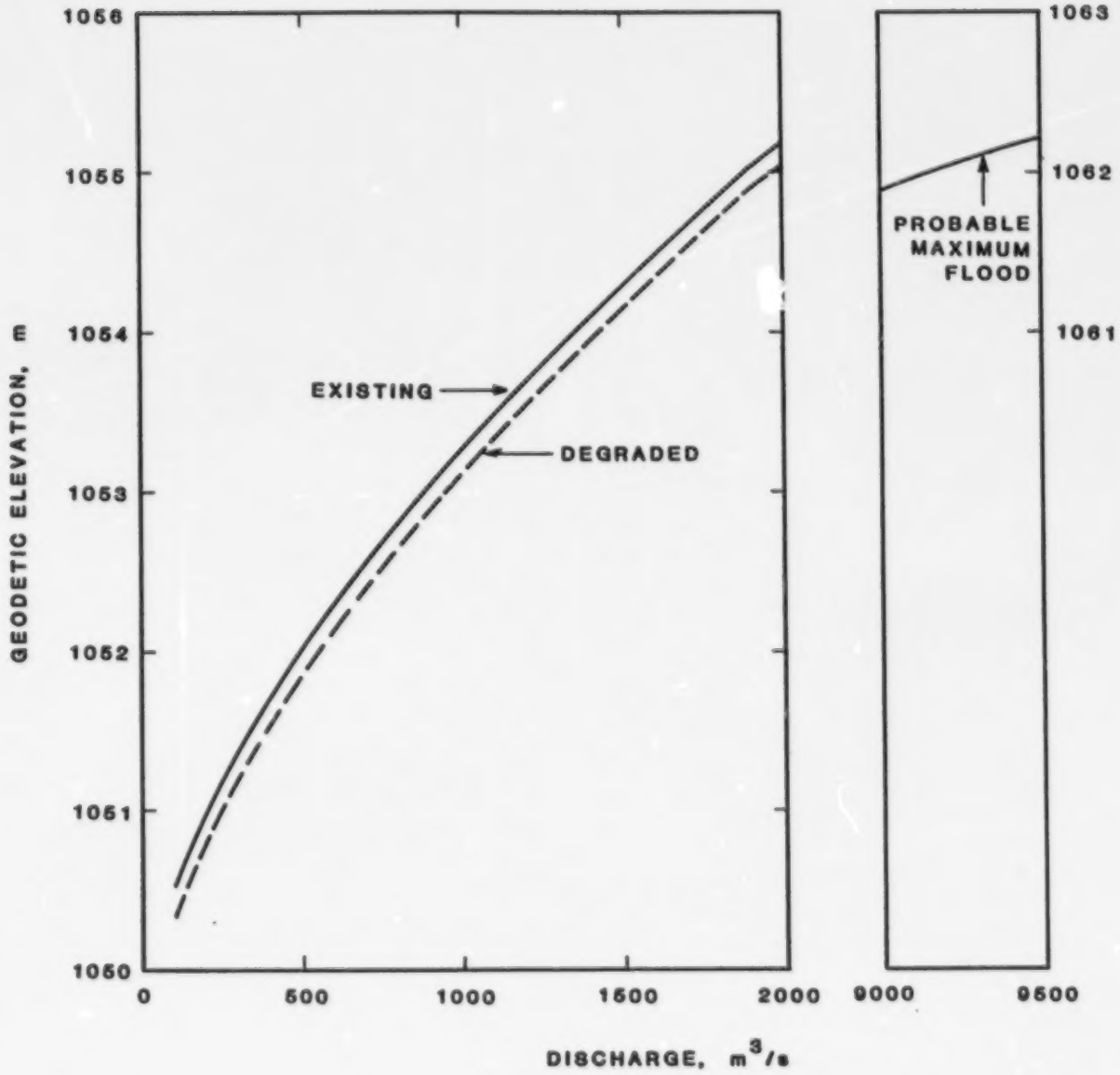


NOTES:

- NELIGIBLE AGGRADATION EXPECTED IN THE CROWSNEST RIVER.
- ASSESSMENT IS BASED ON RESERVOIR HELD AT FULL SUPPLY LEVEL.

FIGURE 19

AGGRADATION AT HEAD OF RESERVOIR

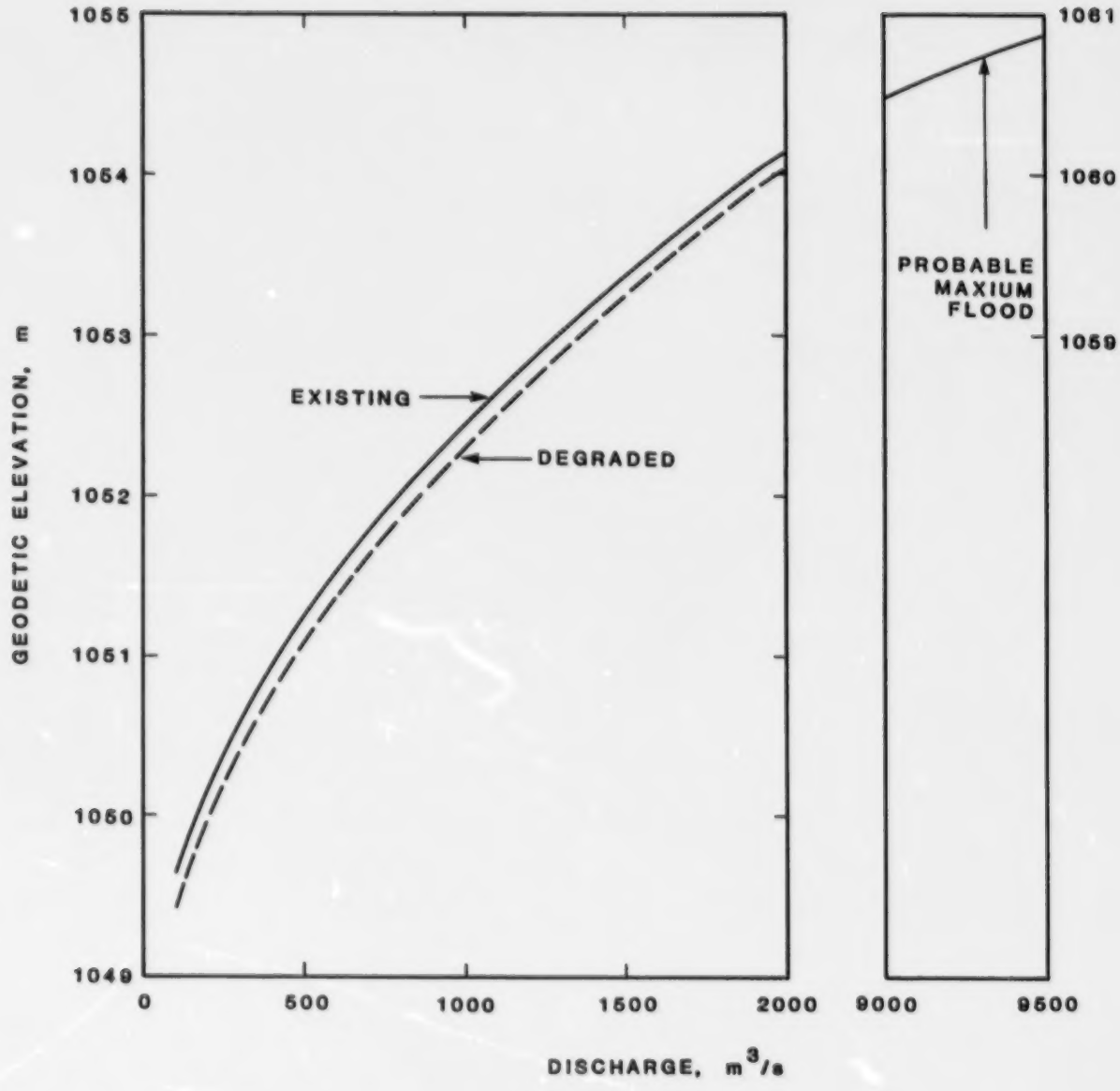


NOTE:

- SEE FIGURE 2 FOR LOCATION.

FIGURE 20

TAILWATER RATING CURVE
FOR SPILLWAY FLIP BUCKET



NOTE:

- SEE FIGURE 2 FOR LOCATION.

FIGURE 21

TAILWATER RATING CURVE
FOR DIVERSION TUNNEL OUTLET

PHOTO 1. Eroding left bank on the Upper Oldman River approximately 17 km north of Cowley and 10 km upstream of the head of the reservoir. Bank contains fines with cobble layers just below terrace level. Note cobbles on bar. 24 May, 1985. (NHCL 895/1-15).

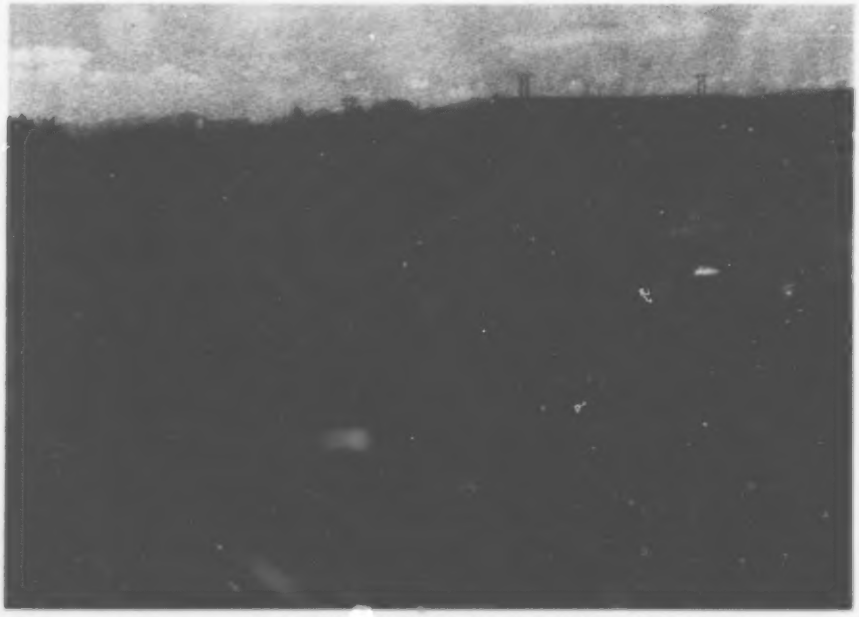


PHOTO 2. View upstream on the Castle River approximately 6 km south of Cowley and 3 km upstream of the head of the reservoir. The left bank (right of photo) is under attack from the flow but is only showing minor erosion. 23 May 1985. (NHCL 895/1-1).

PHOTO 3. View upstream on the Crowsnest River approximately 3 km northwest of Cowley and 5 km upstream of the confluence with the Oldman River and within the reservoir. Note bedrock outcrops along the right bank. 23 may 1985 (NHCL 895/1-5).

PHOTO 4. View upstream on the Oldman River 1 km below the damsite. Note the cobble paved point bar and sandstone outcrops along the left side of the channel and the tree covered island on the right side of the channel. The proposed diversion tunnels outlet is on the left bank halfway up the right edge of the photo. 28 June 1985. (NHCL 895/2-16).

PHOTO 5. Left bank of Oldman River 1.3 km below damsite. Bank material consists of gravels and cobbles. 28 June 1985. (NHCL 895/2-18).

PHOTO 6. Oldman River 1.5 km below the damsite at the location of test pit TP85H102. Bedrock outcropping is visible along the toe of the right valley wall on the opposite side of the river. 28 June 1985. (NHCL 895/2-21).

PHOTO 7. Oldman River test pit TP85H003 approximately 2.4 km below the damsite. Note the large cobbles that form the surface material. 27 June 1985. (NHCL 895/2-6).

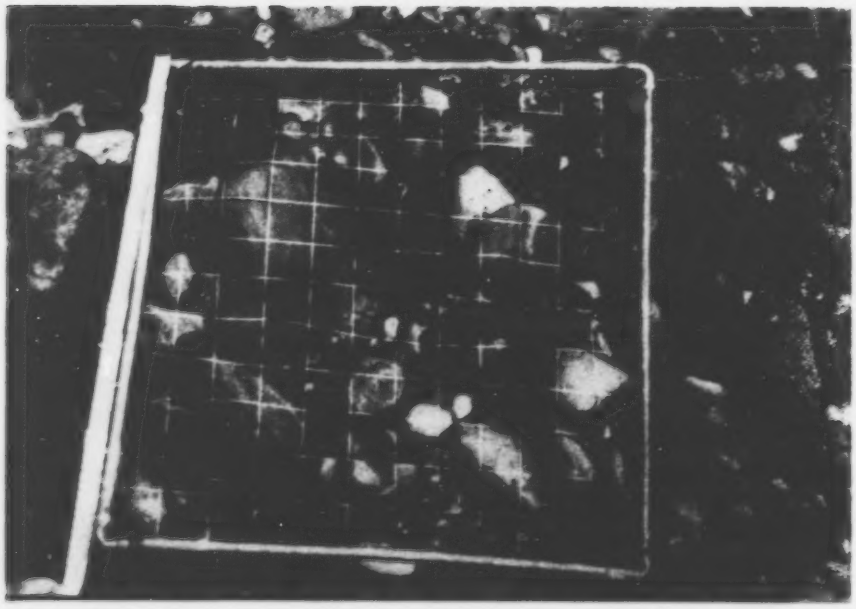


PHOTO 8. Bed material excavated from a depth of 2.0 m from pit TP85H003. The grid is 600 mm square and the large stone to the left of the grid is about 200 mm in size. 27 June 1985. (NHCL 895/2-12).

PHOTO 9. Point bar (see Photo 4) on Oldman River 1 km below damsite showing imbrication of large surface stones. Flow right to left. Grid in centre of photo is 600 mm square. 28 June 1985. (NHCL 895/2-14).

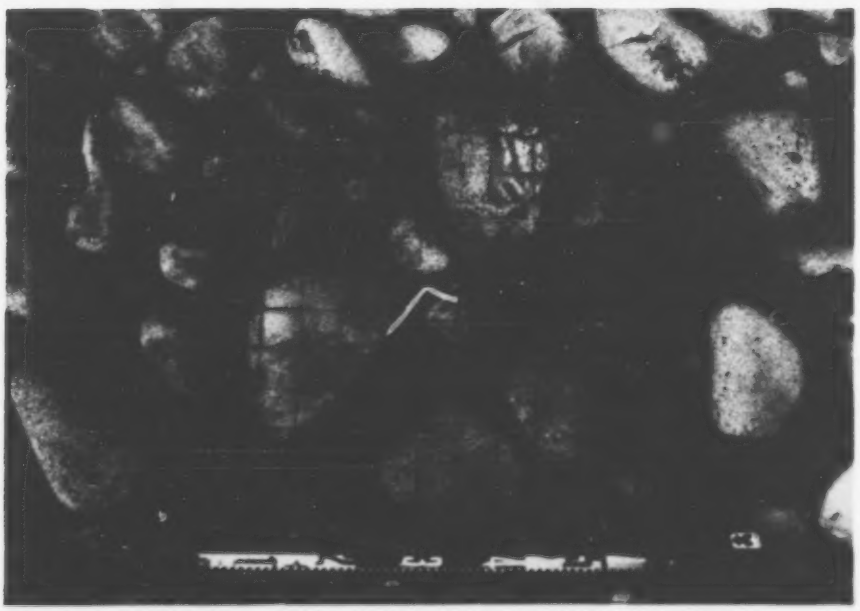


PHOTO 10. Close up of large surface stones on point bar shown in Photo 9. The grid is 600 mm square. 28 June 1985. (NHCL 895/2-13).

APPENDIX A

CROSS-SECTION DATA, OLDMAN RIVER AND TRIBUTARIES

Oldman River

The location of 30 cross-sections of the Oldman River over an 8 km reach from 1 km upstream to 7 km downstream of the damsite are shown in Figure A.1. The river channel and floodplain of the cross-sections were surveyed by Brown, Okamura and Associates Ltd. during the summer of 1985. The sections were extended up the valley walls using 1:5000 scale mapping compiled by Western Photogammetry from aerial photography of September 1984.

The cross-sections are plotted in Figures A.2 to A.11. Table A.1 lists the cross-section coordinates and Table A.2 lists the northings and eastings of salient points on the cross-sections.

Tributaries

The location of cross-sections on the Upper Oldman, Crowsnest and Castle Rivers are shown in Figures A.12 to A.14 respectively. The cross-sections were compiled in an identical manner to the Oldman River sections. Figures A.15 through A.21 show plots of the cross-sections. Table A.3 lists the cross-section coordinates of the three data sets.

SECTION COORDINATES IN METRES

OLDMAN OD-12		OLDMAN OD-11.9		OLDMAN OD-11		OLDMAN OD-10		OLDMAN OD-9	
HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT
10.00	1050.01	0.0	1052.89	0.0	1058.17	0.0	1056.89	12.01	1060.00
29.89	1047.99	60.05	1039.00	5.00	1056.89	5.00	1055.00	36.01	1055.00
48.99	1046.01	114.81	1039.00	8.30	1056.01	8.00	1050.01	54.99	1051.89
65.01	1045.01	148.86	1040.01	18.99	1050.01	10.00	1046.89	60.02	1050.01
300.01	1044.00	230.12	1040.01	27.01	1045.01	68.00	1045.01	80.53	1046.01
304.80	1043.22	255.12	1038.00	30.48	1043.64	91.00	1044.46	91.44	1044.78
313.09	1042.63	262.13	1035.71	38.99	1041.74	97.70	1042.46	95.44	1044.16
324.15	1044.02	308.98	1035.89	44.87	1043.14	106.00	1042.76	102.23	1044.06
334.94	1035.42	330.10	1038.00	57.67	1042.14	115.80	1042.36	110.55	1043.36
338.75	1036.02	358.97	1038.39	64.96	1042.44	146.70	1041.66	115.95	1043.36
347.14	1035.52	405.08	1036.59	71.38	1039.73	153.90	1041.26	127.96	1042.57
356.83	1036.01	415.14	1039.00	78.49	1042.84	184.60	1041.26	145.85	1042.96
374.84	1035.92	440.06	1040.01	88.09	1041.74	188.05	1041.66	176.25	1043.36
378.51	1036.72	665.07	1040.01	137.26	1042.84	184.60	1042.06	181.84	1044.86
414.98	1038.42	690.07	1050.01	181.89	1042.34	187.00	1044.66	206.53	1047.06
425.98	1037.02			225.09	1042.23	202.59	1048.06	213.63	1046.87
434.00	1038.22			284.58	1041.10	210.01	1055.00	225.25	1042.76
440.16	1036.56			295.47	1040.70			239.73	1042.86
445.10	1040.72			307.78	1040.60			249.75	1046.36
452.20	1042.52			343.05	1040.70			259.05	1047.66
455.01	1044.00			361.88	1041.11			274.99	1050.01
485.00	1045.01			380.84	1041.20			320.01	1055.00
505.00	1045.01			404.07	1040.80			330.01	1050.00
705.00	1050.01			420.81	1040.23				
				430.41	1039.13				
				447.20	1038.64				
				467.81	1038.53				
				482.50	1042.07				
				490.21	1042.03				
				518.01	1042.58				
				537.00	1045.01				
				548.01	1050.01				
				566.01	1055.00				

SECTION COORDINATES IN METRES

OLDMAN OD-8		OLDMAN OD-7		OLDMAN OD-6		OLDMAN OD-5.1		OLDMAN OD-5	
HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT
0.0	1062.01	15.00	1060.00	5.48	1055.00	5.48	1055.00	15.88	1070.00
5.00	1060.00	32.48	1056.89	30.48	1051.01	20.48	1052.01	85.01	1060.00
8.98	1056.89	38.89	1055.00	68.48	1055.00	55.47	1050.00	95.01	1058.00
15.87	1055.00	38.01	1051.01	74.48	1052.88	85.47	1057.00	130.00	1055.00
33.98	1052.89	58.00	1050.01	75.47	1051.88	115.48	1052.00	130.00	1052.00
30.48	1050.16	91.44	1048.21	86.47	1050.01	140.48	1051.01	148.88	1051.01
34.28	1048.06	101.35	1048.10	187.67	1048.30	180.47	1050.80	200.01	1051.35
35.33	1044.76	105.74	1045.80	189.98	1047.89	230.47	1051.18	203.51	1051.29
48.66	1043.46	110.34	1045.20	188.77	1048.98	232.47	1051.18	208.21	1048.78
53.66	1043.76	115.73	1045.10	204.67	1048.58	238.18	1050.48	218.21	1047.79
58.67	1043.24	124.75	1045.71	210.77	1048.68	242.47	1049.48	225.88	1047.29
78.67	1043.36	127.83	1045.10	217.87	1047.30	244.97	1048.38	231.10	1047.20
90.37	1044.36	137.63	1045.80	224.48	1047.28	248.70	1047.68	251.80	1047.89
100.77	1047.36	148.83	1045.60	231.47	1048.88	256.58	1047.08	265.38	1047.89
108.46	1047.56	158.08	1046.70	243.78	1048.88	262.37	1048.78	278.41	1047.89
174.77	1047.46	203.03	1047.20	265.27	1046.60	278.67	1048.88	288.88	1048.48
224.18	1048.86	220.74	1047.20	273.58	1048.28	286.67	1048.58	294.61	1048.09
248.88	1048.86	241.04	1047.80	278.98	1045.88	291.97	1048.58	300.41	1049.09
265.67	1048.16	244.46	1047.80	282.88	1048.18	296.68	1048.18	304.40	1049.89
301.97	1048.36	248.33	1048.90	287.68	1047.68	301.97	1045.78	313.78	1047.89
316.28	1047.46	258.15	1047.11	300.47	1050.00	307.78	1047.18	319.19	1048.09
336.77	1048.46	263.83	1048.60	308.49	1048.00	311.48	1048.88	321.88	1047.20
364.08	1047.66	278.88	1051.01			321.41	1055.00	334.01	1047.09
376.88	1046.76	306.01	1050.00			330.48	1060.00	347.80	1052.48
380.40	1046.86					338.48	1070.00	351.00	1060.85
414.88	1060.00							355.00	1070.00

TABLE A.1

OLDMAN RIVER
CROSS-SECTION COORDINATES

SECTION COORDINATES IN METRES

OLDMAN 00-4		OLDMAN 00-3		OLDMAN 00-2		OLDMAN 00-1		OLDMAN 00-26	
HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT
44.98	1070.00	64.98	1070.00	5.00	1070.00	5.49	1070.00	84.01	1070.00
70.01	1060.00	100.00	1056.16	62.00	1060.00	30.48	1060.00	83.00	1060.00
86.01	1055.00	108.86	1050.28	100.00	1054.35	40.48	1058.00	147.01	1055.00
100.00	1052.26	120.37	1048.46	102.36	1054.26	65.47	1056.00	200.01	1052.89
108.23	1048.66	126.16	1048.36	103.65	1052.16	125.49	1055.00	202.89	1051.19
112.23	1048.97	133.17	1047.57	109.30	1051.96	130.48	1053.21	208.81	1049.58
132.53	1047.35	154.17	1047.76	113.39	1049.67	134.39	1052.72	216.60	1048.69
155.84	1047.26	160.66	1047.96	126.10	1049.46	141.37	1049.44	227.89	1049.59
156.95	1047.46	165.66	1048.36	158.80	1048.36	149.11	1048.72	233.51	1049.78
169.44	1050.26	168.65	1051.18	166.18	1048.36	154.41	1048.82	244.78	1049.29
179.85	1050.37	186.65	1051.77	185.38	1050.65	173.80	1049.12	248.90	1048.60
183.34	1049.67	197.36	1050.46	187.60	1051.25	200.41	1050.43	255.81	1048.39
189.04	1049.36	211.17	1051.26	208.18	1051.26	205.92	1050.72	258.51	1048.38
201.53	1049.36	226.17	1051.66	214.00	1051.76	216.31	1050.52	280.91	1049.78
207.05	1050.46	233.67	1051.56	216.90	1051.96	220.10	1049.63	282.88	1051.69
212.63	1050.65	264.17	1051.56	220.28	1051.65	227.81	1049.81	284.81	1052.41
232.75	1050.07	274.47	1050.98	235.18	1051.77	231.71	1049.03	289.99	1050.00
235.43	1050.36	276.45	1049.86	252.69	1050.85	236.52	1051.32	293.83	1070.00
247.53	1049.85	301.87	1049.66	269.20	1048.55	248.47	1060.00		
261.73	1051.16	315.26	1050.26	274.08	1048.65	258.47	1070.00		
280.14	1050.85	320.01	1060.00	282.18	1051.16				
285.14	1048.97	345.00	1070.00	284.98	1051.35				
293.03	1048.06			285.48	1050.86				
300.65	1048.76			300.01	1060.00				
306.24	1049.06			315.01	1070.00				
309.43	1049.46								
320.01	1060.00								
331.89	1070.00								

SECTION COORDINATES IN METRES

OLDMAN 00-27		OLDMAN 00-26		OLDMAN 00-25		OLDMAN 00-24		OLDMAN 00-23	
HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT
0.0	1070.00	44.88	1088.84	71.88	1070.00	78.00	1070.00	74.01	1070.00
18.00	1060.00	70.01	1080.00	100.00	1064.61	100.00	1065.78	90.01	1080.00
64.88	1055.00	85.01	1068.00	108.38	1063.01	109.38	1064.06	100.00	1065.08
100.00	1052.09	100.00	1063.83	109.38	1061.71	112.58	1061.88	101.80	1064.48
108.11	1052.48	103.81	1063.78	112.90	1061.11	117.58	1061.88	104.00	1062.88
117.20	1048.70	108.81	1062.26	123.90	1062.02	126.00	1061.28	108.21	1061.77
123.98	1048.48	114.51	1061.44	133.58	1062.01	148.80	1061.28	112.41	1060.85
130.21	1048.89	118.89	1060.76	146.40	1061.81	158.21	1061.36	121.18	1060.36
143.41	1050.58	123.80	1060.36	158.68	1061.81	163.80	1061.28	133.20	1060.66
147.71	1050.38	128.18	1061.16	166.30	1061.30	170.81	1060.88	149.28	1060.76
160.91	1061.18	147.18	1061.86	176.40	1061.82	176.18	1060.88	166.91	1061.85
170.80	1048.97	168.01	1061.74	215.71	1060.80	197.38	1061.58	174.18	1062.57
178.18	1048.38	207.38	1060.25	224.00	1060.41	204.80	1062.18	189.40	1062.48
182.38	1048.18	214.30	1048.85	236.48	1060.11	243.41	1061.88	201.58	1062.18
187.61	1048.78	222.80	1060.85	242.71	1060.51	247.18	1063.58	228.40	1062.86
206.88	1048.87	238.00	1060.74	246.18	1060.92	261.00	1063.36	238.31	1063.05
211.41	1053.64	244.38	1048.85	248.60	1062.81	263.20	1064.78	242.28	1066.66
217.88	1060.00	268.01	1048.85	252.10	1064.31	284.88	1068.00	244.88	1068.00
227.88	1070.00	282.71	1048.85	288.01	1068.00	297.00	1060.00	340.00	1060.00
		288.70	1060.45	308.00	1060.00	338.01	1070.00	388.00	1070.00
		288.80	1061.32	330.04	1070.00				
		298.01	1068.00						
		303.00	1070.00						

TABLE A.1 (Cont.)

SECTION COORDINATES IN METRES

OLDMAN OD-22		OLDMAN OD-21		OLDMAN OD-20		OLDMAN OD-19		OLDMAN OD-18	
HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT
75.99	1070.00	75.01	1070.00	75.01	1070.00	76.99	1070.00	75.01	1070.00
100.00	1052.50	100.00	1053.42	100.00	1053.16	100.00	1053.44	100.00	1053.17
108.70	1050.84	102.99	1051.76	105.49	1050.28	106.98	1052.06	104.39	1052.27
114.79	1050.42	115.40	1050.76	108.30	1050.96	111.89	1051.66	112.11	1052.47
124.79	1050.79	122.98	1050.41	110.69	1050.86	116.01	1051.86	116.29	1053.17
134.59	1050.60	128.38	1050.85	113.29	1050.07	120.00	1051.89	134.81	1053.76
145.79	1050.09	135.79	1051.46	117.60	1051.36	124.78	1051.76	144.60	1053.77
156.09	1051.69	150.38	1051.76	127.89	1051.86	126.80	1051.46	155.79	1053.37
165.61	1052.66	158.20	1052.66	134.60	1052.06	128.41	1051.86	175.11	1053.57
180.41	1052.86	175.50	1053.46	156.30	1051.66	136.48	1052.36	177.30	1054.47
207.68	1052.50	187.09	1053.27	187.79	1053.86	141.79	1053.06	183.91	1055.16
214.78	1051.98	198.88	1053.86	188.31	1054.56	153.86	1053.56	206.28	1055.37
231.10	1053.28	216.80	1052.86	193.30	1054.56	158.31	1052.76	216.91	1055.17
237.80	1055.79	233.28	1052.46	195.10	1054.16	165.68	1052.16	219.21	1053.67
278.88	1057.00	242.59	1057.36	200.10	1054.64	172.70	1051.86	221.71	1052.77
330.01	1056.98	278.89	1057.89	202.11	1054.48	182.70	1051.66	224.48	1052.26
355.00	1058.00	320.01	1056.40	213.70	1054.48	235.31	1053.06	238.40	1052.17
365.00	1060.00	345.00	1060.00	224.00	1054.26	250.52	1053.76	265.20	1053.17
369.99	1070.00	368.98	1070.08	232.71	1053.76	267.40	1053.86	303.78	1054.07
				241.40	1052.56	283.48	1054.26	306.80	1054.47
				248.81	1052.57	280.20	1052.86	324.68	1055.18
				260.81	1053.88	288.80	1052.86	333.78	1054.70
				265.21	1054.18	300.20	1053.36	341.41	1053.80
				282.10	1057.06	305.01	1053.86	345.80	1054.40
				318.00	1058.00	308.40	1052.56	361.01	1053.70
				330.01	1060.00	323.21	1057.75	366.18	1053.80
				368.89	1070.00	373.61	1058.00	384.38	1058.00
						378.98	1060.00	404.01	1060.00
						440.00	1070.00	443.00	1070.00

SECTION COORDINATES IN METRES

OLDMAN OD-17		OLDMAN OD-16		OLDMAN OD-14		OLDMAN OD-13	
HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT
76.88	1070.00	71.88	1070.00	54.89	1070.00	75.01	1070.00
100.00	1054.42	100.00	1054.86	100.00	1054.89	100.00	1056.30
110.81	1052.72	104.70	1054.81	105.10	1053.19	104.78	1054.16
112.50	1052.02	108.78	1053.81	112.11	1052.59	112.28	1052.30
117.90	1051.82	116.71	1052.81	120.79	1052.88	126.31	1052.30
120.61	1052.41	131.88	1053.81	125.21	1052.88	127.19	1052.80
128.61	1053.22	141.40	1053.81	140.91	1054.00	140.08	1054.00
140.70	1053.72	160.11	1053.41	141.81	1054.30	185.61	1054.80
162.78	1053.72	164.31	1053.41	144.41	1054.28	188.88	1056.80
173.00	1055.52	174.18	1053.21	150.30	1053.88	170.89	1056.30
180.82	1055.61	183.88	1053.61	163.59	1054.30	180.20	1056.41
187.11	1055.12	188.81	1055.10	194.69	1056.49	246.71	1056.30
201.88	1055.52	216.89	1055.71	211.81	1056.58	263.31	1056.80
251.18	1055.12	232.81	1055.71	230.18	1056.28	267.78	1056.80
283.41	1055.31	251.48	1056.81	248.11	1056.18	283.40	1056.80
287.10	1054.21	288.88	1055.81	287.09	1055.68	288.80	1057.11
288.88	1053.01	307.70	1055.80	305.28	1055.80	304.80	1056.80
272.08	1052.31	342.64	1056.32	308.80	1054.20	305.28	1056.30
276.08	1052.11	345.09	1056.32	310.80	1052.80	308.31	1053.40
281.80	1052.11	348.38	1053.22	325.10	1052.70	314.80	1052.80
328.40	1053.51	351.89	1052.52	340.80	1052.88	321.81	1052.81
348.80	1054.41	356.80	1052.42	351.10	1053.00	343.11	1053.00
351.80	1054.21	368.81	1052.63	365.78	1053.70	366.48	1053.40
372.58	1058.88	388.80	1833.22	366.61	1055.60	381.10	1054.20
393.01	1060.00	388.68	1063.32	373.20	1056.83	383.80	1056.30
404.88	1070.00	410.29	1063.72	381.00	1060.00	387.80	1056.88
		414.10	1065.48	387.00	1070.00	375.00	1060.00
		418.01	1060.00			389.88	1070.00
		445.88	1070.00				

TABLE A.1 (Cont.)

TABLE A.2

LOCATION COORDINATES OF OLDMAN RIVER CROSS-SECTIONS

Cross Section	Horizontal Distance m	Coordinates Northing m	Coordinates Easting m
OD-12	304.80	90929.639	12887.799
	452.20	90787.535	12926.808
OD-11	30.48	90569.630	11791.113
	490.21	90118.975	11878.455
OD-10	91.00	90559.894	10510.500
	202.59	90448.365	10507.902
OD- 9	91.44	90882.405	10078.936
	259.05	90746.669	9981.770
OD- 8	30.48	91222.273	9431.687
	388.40	90865.281	9411.010
OD- 7	91.44	91076.407	8797.431
	263.93	90933.464	8879.049
OD- 6	182.87	90991.443	8688.876
	287.58	90900.821	8741.257
OD-5.1	230.47	90878.103	8300.734
	311.69	90796.982	8303.773
OD- 5	200.01	90908.366	8198.978
	347.50	90782.946	8121.428
OD- 4	100.00	90963.993	8072.674
	309.43	90819.202	8014.724
OD- 3	100.00	1140.166	7723.463
	315.25	90955.558	7613.847
OD- 2	100.00	1198.473	7570.088
	285.49	1023.760	7513.777
OD- 1	130.48	1239.717	7446.263
	236.52	1159.728	7376.707

TABLE A.2 Continued

Cross Section	Horizontal Distance m	Coordinates Northing m	Coordinates Easting m
OD-28	200.01	1322.743	7359.909
	264.81	1278.475	7312.680
OD-27	100.00	1424.719	7344.807
	211.41	1433.540	7233.738
OD-26	100.00	1516.957	7373.901
	268.80	1569.639	7213.528
OD-25	100.00	1611.508	7406.207
	252.10	1691.547	7276.957
OD-24	100.00	1698.110	7447.167
	253.20	1789.825	7324.443
OD-23	100.00	1792.269	7488.043
	242.29	1877.443	7374.071
OD-22	100.00	1880.667	7536.594
	237.80	1963.129	7426.251
OD-21	100.00	1998.335	7583.338
	242.59	2039.980	7447.037
OD-20	100.00	2123.771	7615.569
	262.10	2115.873	7453.705
OD-19	100.00	2299.213	7637.493
	323.21	2178.793	7449.681
OD-18	100.00	2421.066	7632.957
	364.39	2254.357	7427.816
OD-17	100.00	2550.800	7566.281
	372.58	2332.221	7403.582
OD-15	100.00	2468.104	7381.086
	414.10	2402.219	7353.569

TABLE A.2 Continued

Cross Section	Horizontal Distance m	Coordinates Northing m	Coordinates Easting m
OD-14	100.00	2698.178	7321.163
	373.20	2430.211	7268.335
OD-13	367.80	2711.026	7176.843
	367.80	2443.306	7182.342

Note: The horizontal distances correspond to the underlined values of the cross-section coordinates (Table A.1).

SECTION COORDINATES IN METRES

OLDMAN R OU-4		OLDMAN R OU-3		OLDMAN R OU-2		OLDMAN R OU-1		OLDMAN R O-1	
HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT
0.0	1120.00	85.00	1120.00	25.00	1125.00	0.0	1127.98	0.0	1091.87
22.00	1110.00	100.00	1111.80	75.00	1119.00	2.40	1127.40	14.20	1091.01
30.00	1105.00	103.50	1109.77	100.00	1116.30	10.20	1126.85	18.50	1090.44
33.00	1100.00	105.60	1109.48	101.00	1116.20	25.00	1126.84	23.00	1087.71
40.00	1098.00	116.40	1110.21	103.80	1117.00	45.00	1125.80	30.00	1087.84
60.00	1095.00	126.00	1110.13	116.00	1117.40	50.20	1126.84	35.00	1088.21
75.00	1100.00	135.20	1108.42	130.00	1117.20	50.20	1130.00	40.70	1091.01
250.00	1105.00	140.70	1109.78	136.80	1116.40			42.90	1092.34
280.00	1120.00	151.70	1110.29	146.50	1116.00				
		160.70	1110.28	153.50	1116.30				
		164.20	1109.77	157.70	1115.60				
		166.20	1110.23	161.10	1115.60				
		167.20	1111.02	165.80	1116.30				
		207.00	1113.00	168.20	1116.99				
		213.00	1115.00	175.00	1125.00				
		226.00	1126.00						

SECTION COORDINATES IN METRES

CASTLE R C-7		CASTLE R C-6		CASTLE R C-5		CASTLE R C-4		CASTLE R C-3	
HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT
0.0	1125.00	0.0	1125.00	0.0	1125.59	0.0	1125.73	0.0	1128.87
30.00	1110.00	20.00	1120.00	2.00	1123.58	2.40	1125.73	3.40	1128.41
40.00	1108.50	80.00	1119.00	13.50	1121.82	3.70	1124.83	3.40	1127.81
45.00	1108.00	400.00	1117.73	21.00	1121.75	7.10	1124.83	5.10	1127.51
70.00	1107.50	418.20	1117.33	27.90	1119.79	10.70	1123.73	9.80	1127.51
80.00	1106.50	426.40	1117.03	30.30	1120.48	14.40	1124.23	15.20	1127.81
90.00	1110.00	433.80	1116.43	37.80	1120.38	24.40	1124.73	43.10	1127.31
110.00	1125.00	446.80	1115.73	75.90	1121.88	31.40	1124.83	48.90	1127.01
		455.50	1115.03	91.30	1122.38	51.70	1124.43	54.80	1127.31
		464.00	1114.63	120.10	1121.89	56.20	1124.63	72.80	1128.31
		470.50	1115.03	125.10	1121.38	76.80	1124.83		
		472.50	1115.73	126.80	1120.88	82.80	1124.03		
		480.00	1125.00	137.10	1120.89	87.00	1123.13		
				140.70	1122.09	93.00	1121.13		
				280.00	1126.00	96.80	1120.93		
						100.00	1122.63		
						108.00	1122.63		
						111.70	1124.28		

SECTION COORDINATES IN METRES

CASTLE R C-2A		CASTLE R C-2		CROWSNEST R CR-7		CROWSNEST R CR-6		CROWSNEST R CR-5	
HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT
0.0	1130.35	0.0	1131.52	20.00	1120.00	55.00	1120.00	40.00	1120.00
5.20	1128.45	8.40	1128.52	220.00	1115.00	80.00	1110.00	70.00	1118.00
8.00	1128.05	12.10	1128.62	295.00	1105.00	93.00	1105.00	100.00	1116.08
14.10	1128.45	20.10	1127.92	370.00	1100.00	275.00	1105.00	101.50	1113.88
23.80	1128.35	24.50	1128.22	500.00	1098.38	320.00	1105.00	103.40	1112.73
37.10	1127.85	27.00	1128.02	500.30	1097.41	400.00	1104.84	110.00	1112.60
43.10	1127.85	30.40	1128.32	500.50	1095.54	403.20	1104.01	110.10	1112.56
60.30	1128.65	41.30	1128.62	503.80	1094.24	406.00	1103.67	130.00	1112.53
64.80	1129.45	48.30	1128.02	507.00	1093.90	413.00	1103.88	134.30	1112.75
66.70	1131.45	58.80	1130.62	517.00	1093.95	418.00	1103.71	135.40	1113.06
69.10	1131.85	74.50	1131.42	522.00	1094.01	424.50	1103.28	135.50	1114.06
		84.80	1131.02	532.40	1094.24	429.00	1103.51	137.00	1114.55
		102.10	1131.82	538.10	1095.35	431.60	1104.01	185.00	1125.00
				555.00	1100.00	435.10	1104.80		
				610.00	1115.00	450.00	1110.00		
				640.00	1120.00	485.00	1120.00		

SECTION COORDINATES IN METRES

CROWSNEST R CR-4		CROWSNEST R CR-3		CROWSNEST R CR-2		CROWSNEST R CR-1	
HORIZ	VERT	HORIZ	VERT	HORIZ	VERT	HORIZ	VERT
0.0	1124.63	0.0	1127.45	0.0	1130.02	0.0	1137.18
3.10	1123.61	2.50	1126.48	4.50	1128.82	0.50	1137.18
7.00	1123.27	5.50	1125.88	9.00	1128.71	2.50	1135.26
15.00	1123.42	12.00	1126.84	12.00	1128.25	8.00	1134.65
21.00	1123.42	18.00	1126.08	21.00	1128.15	16.00	1134.28
28.00	1123.53	23.50	1126.48	28.00	1127.94	30.00	1134.53
40.00	1123.18	24.50	1127.07	38.00	1128.34	32.00	1135.58
42.00	1123.38	27.00	1127.59	39.20	1132.18	38.80	1143.26
43.50	1124.56	30.00	1127.67	40.20	1132.28		

TABLE A.3

TRIBUTARY
CROSS-SECTION COORDINATES

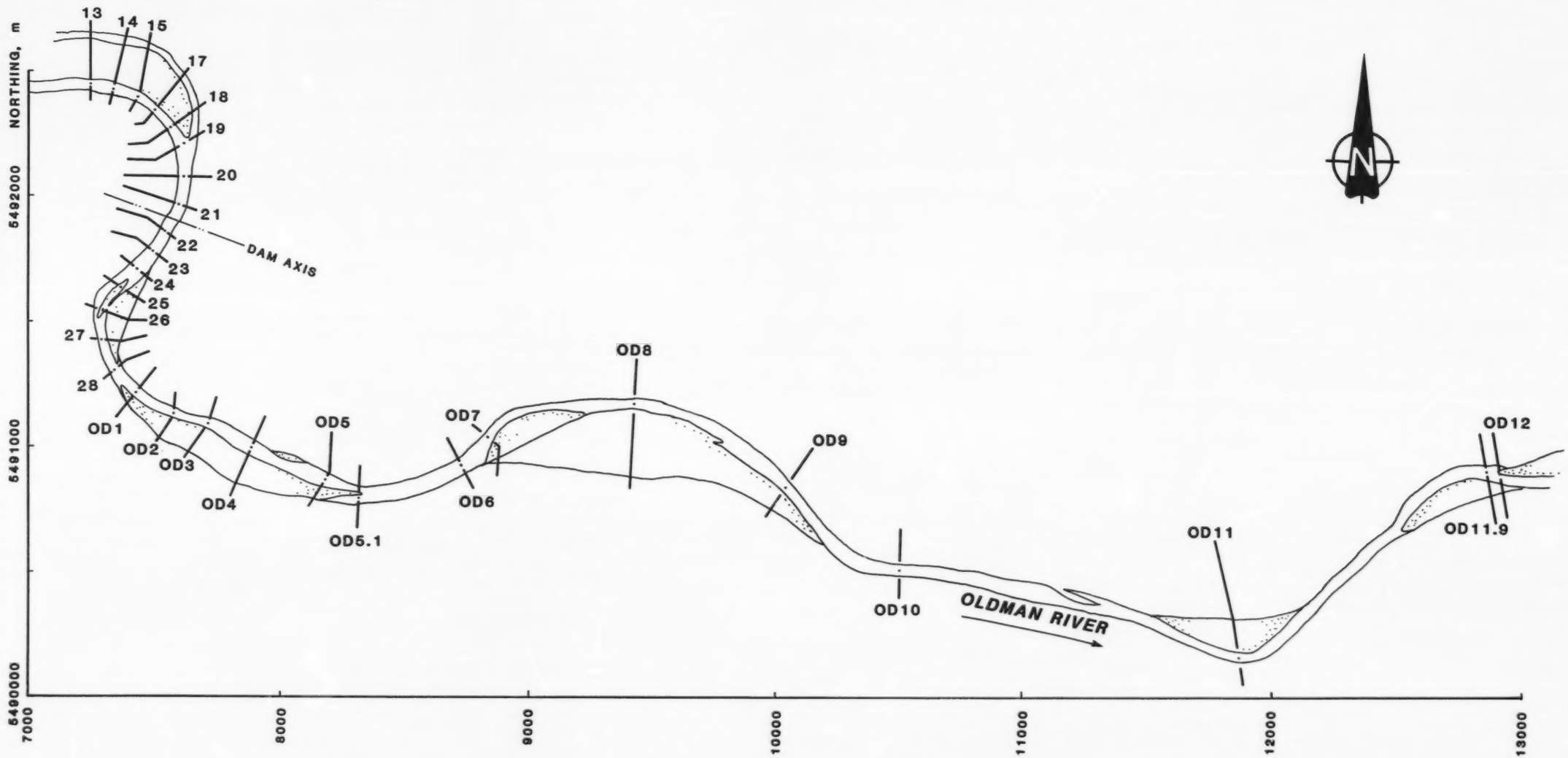
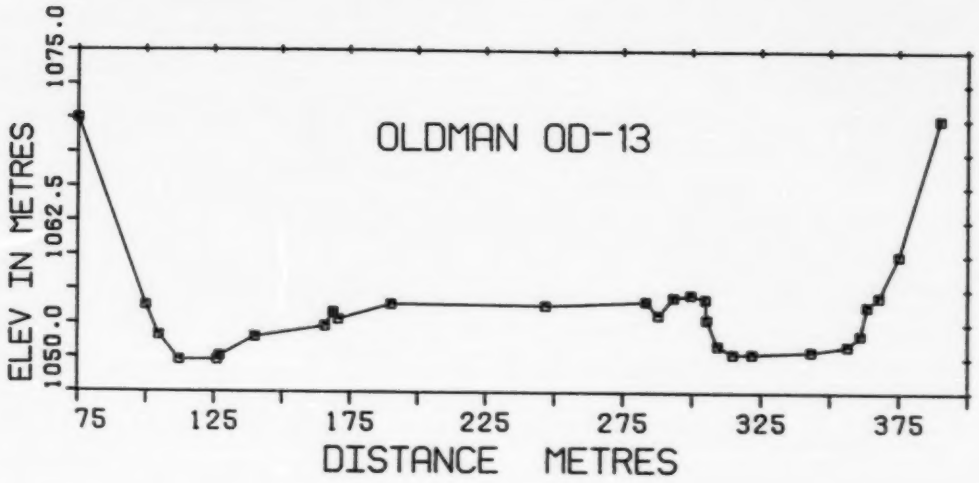
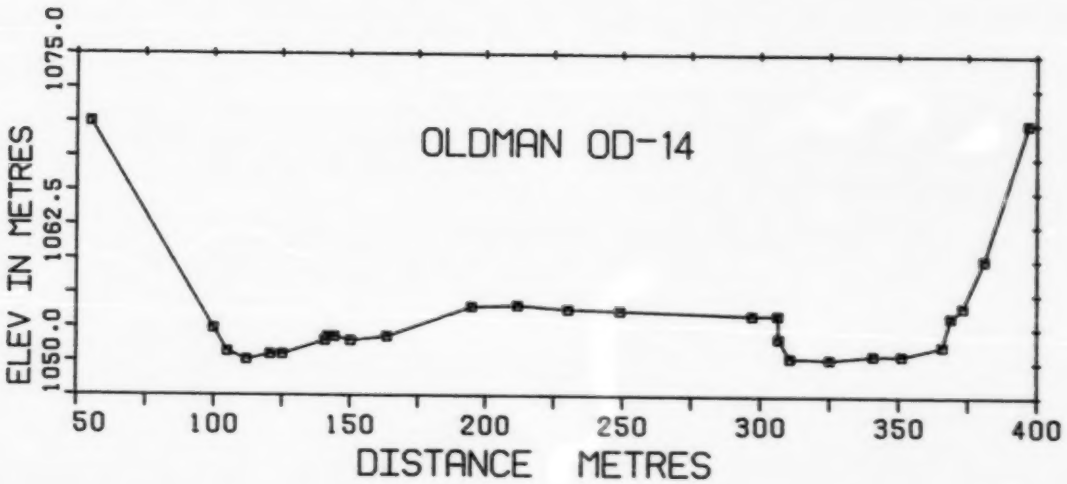


FIGURE A.1

LOCATION OF OLDMAN RIVER CROSS-SECTIONS


OLDMAN OD-13
ELEV IN METRES
1075.0
1062.5
1050.0
75
125
175
225
275
325
375
DISTANCE METRES


OLDMAN OD-14
ELEV IN METRES
1075.0
1062.5
1050.0
50
100
150
200
250
300
350
400
DISTANCE METRES

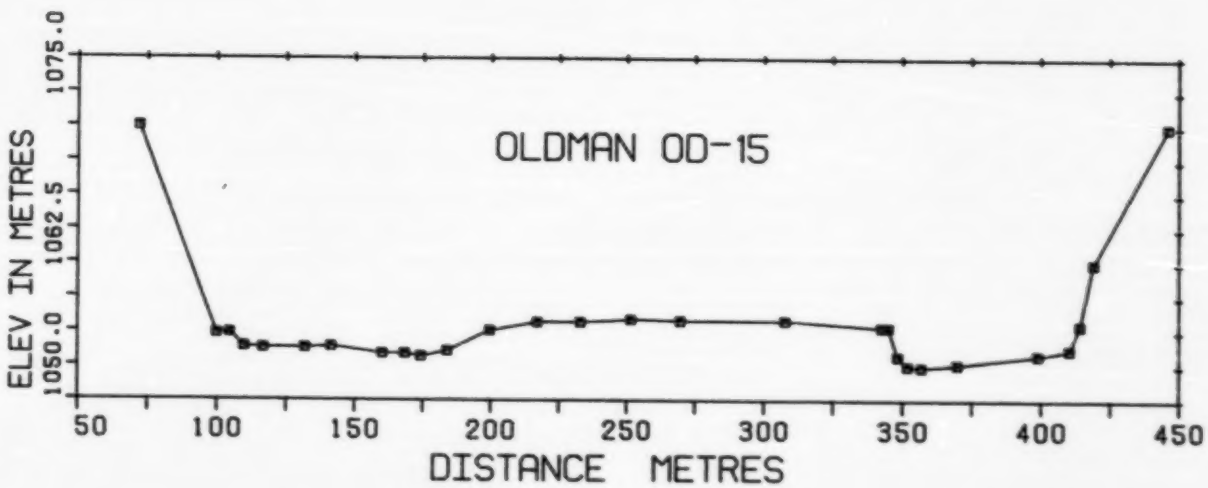
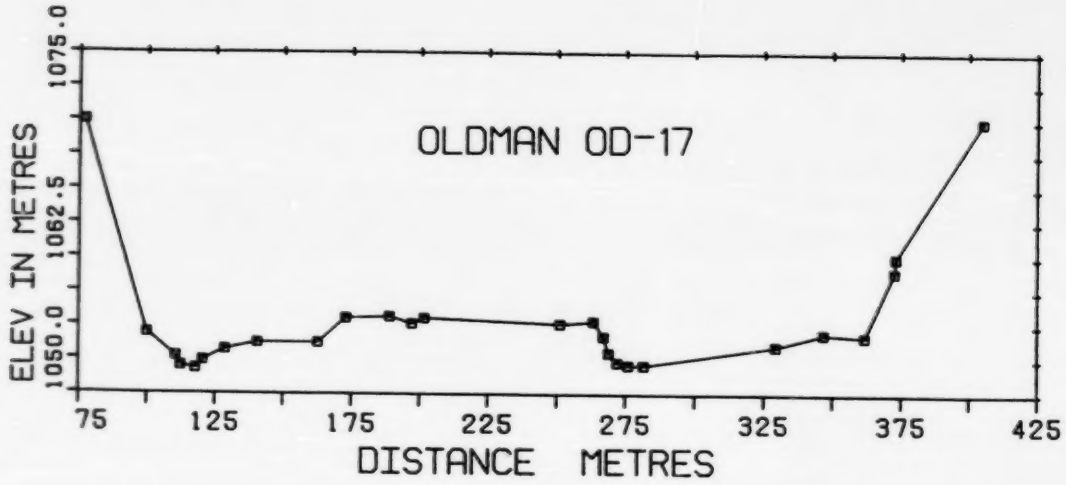
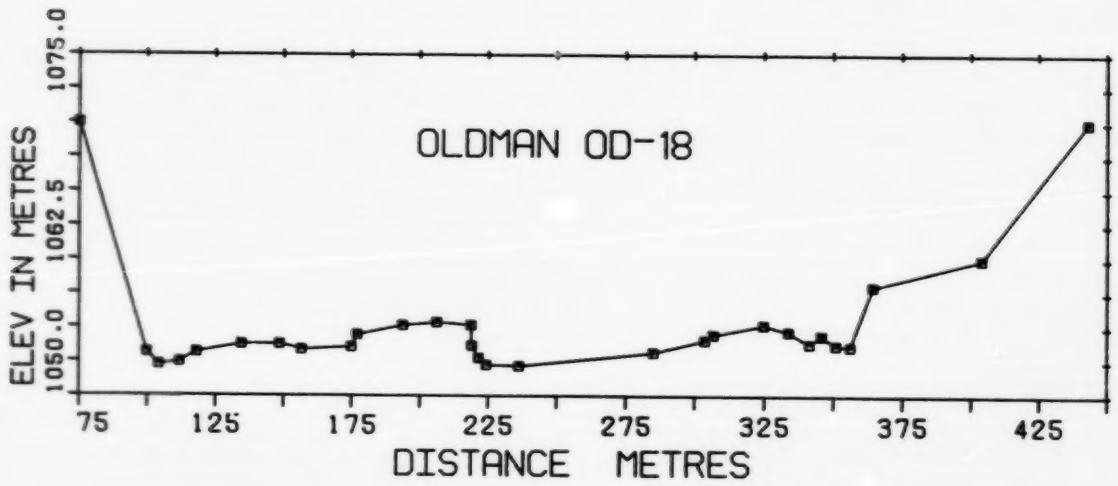

OLDMAN OD-15
ELEV IN METRES
1075.0
1062.5
1050.0
50
100
150
200
250
300
350
400
450
DISTANCE METRES

FIGURE A.2


OLDMAN OD-17
ELEV IN METRES
1075.0
1062.5
1050.0
75
125
175
225
275
325
375
425
DISTANCE METRES


OLDMAN OD-18
ELEV IN METRES
1075.0
1062.5
1050.0
75
125
175
225
275
325
375
425
DISTANCE METRES

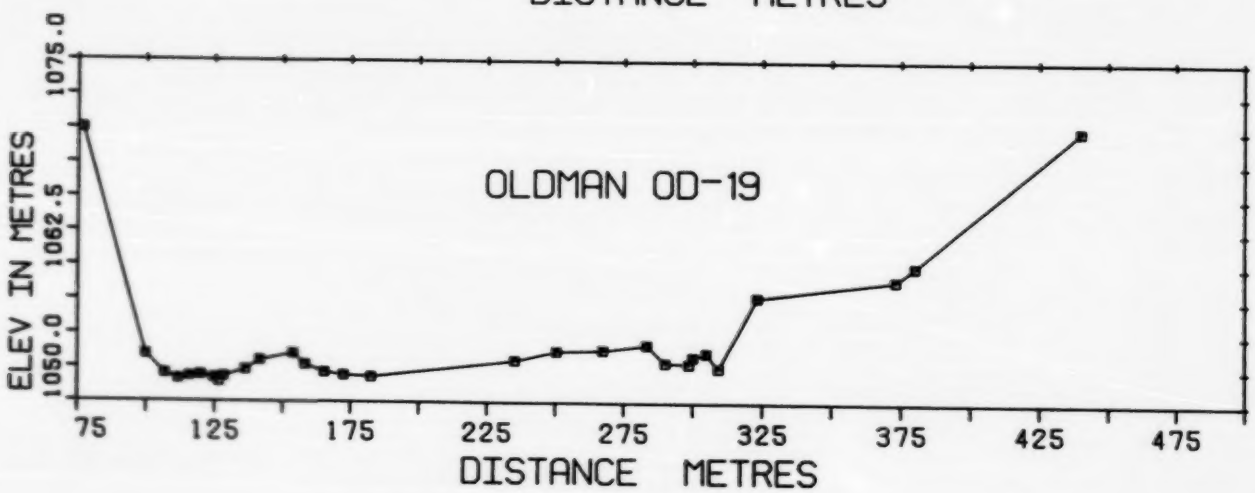
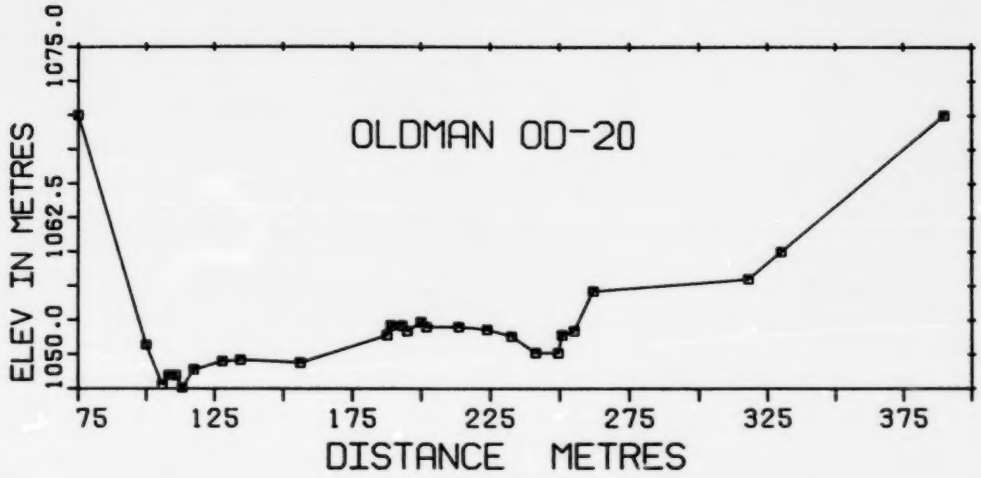

OLDMAN OD-19
ELEV IN METRES
1075.0
1062.5
1050.0
75
125
175
225
275
325
375
425
475
DISTANCE METRES

FIGURE A.3


OLDMAN OD-20
ELEV IN METRES
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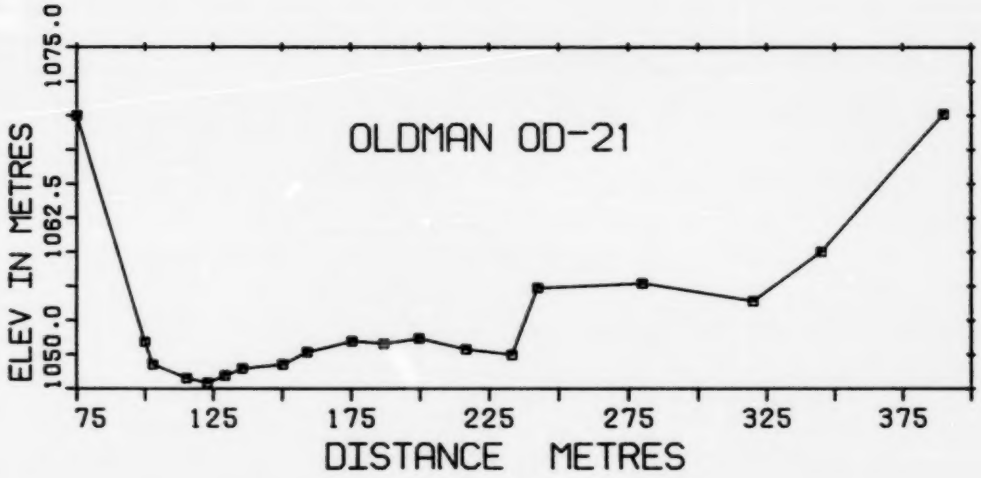
1062.5
1050.0
75
125
175
225
275
325
375
DISTANCE METRES


OLDMAN OD-21
ELEV IN METRES
1075.0
1062.5
1050.0
75
125
175
225
275
325
375
DISTANCE METRES

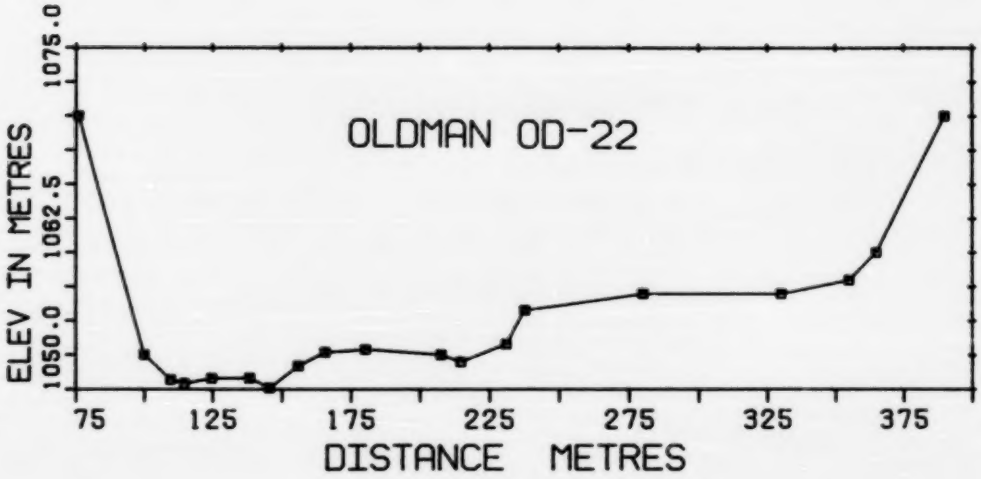
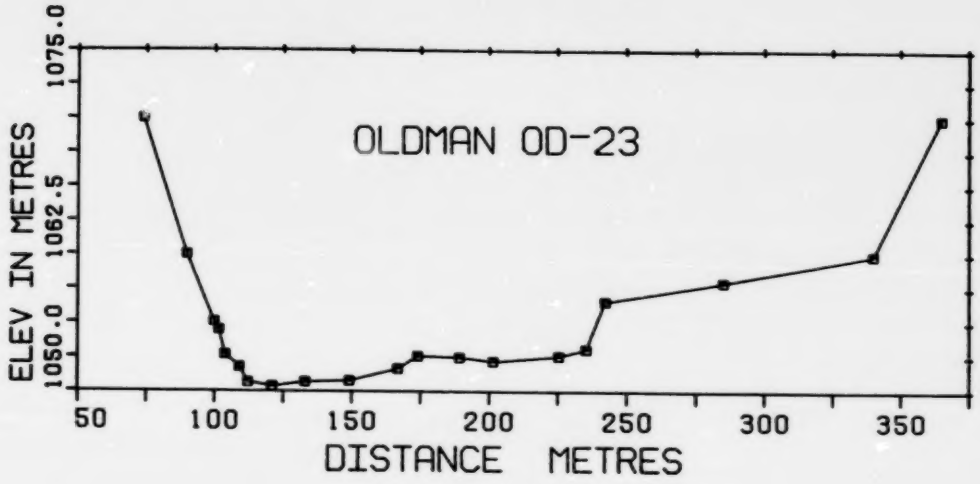
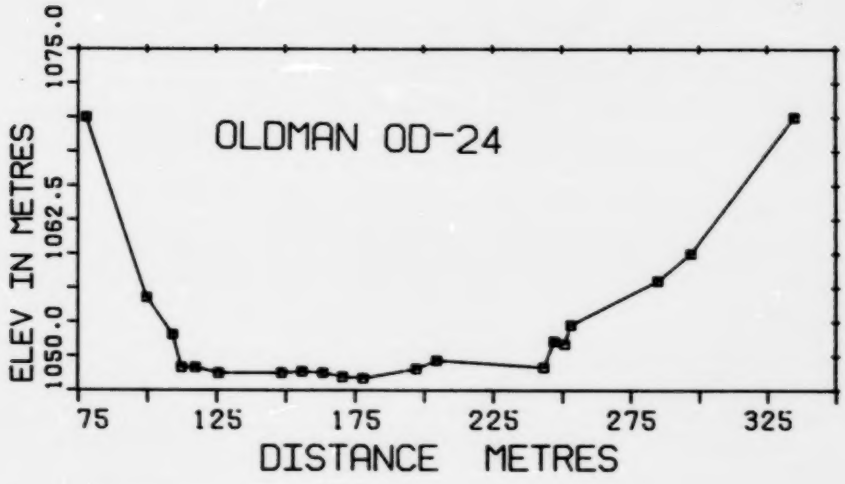

OLDMAN OD-22
ELEV IN METRES
1075.0
1062.5
1050.0
75
125
175
225
275
325
375
DISTANCE METRES

FIGURE A.4


OLDMAN OD-23
ELEV IN METRES
1075.0
1062.5
1050.0
50
100
150
200
250
300
350
DISTANCE METRES


OLDMAN OD-24
ELEV IN METRES
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1062.5
1050.0
75
125
175
225
275
325
DISTANCE METRES

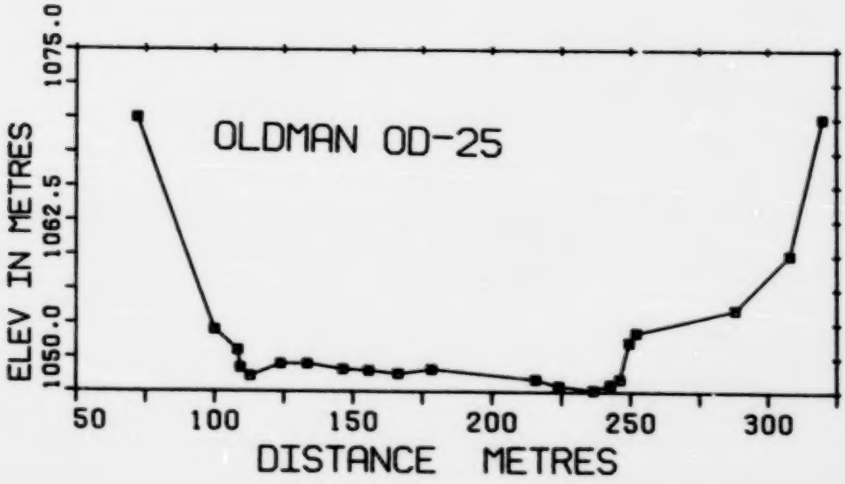

OLDMAN OD-25
ELEV IN METRES
1075.0
1062.5
1050.0
50
100
150
200
250
300
DISTANCE METRES

FIGURE A.5

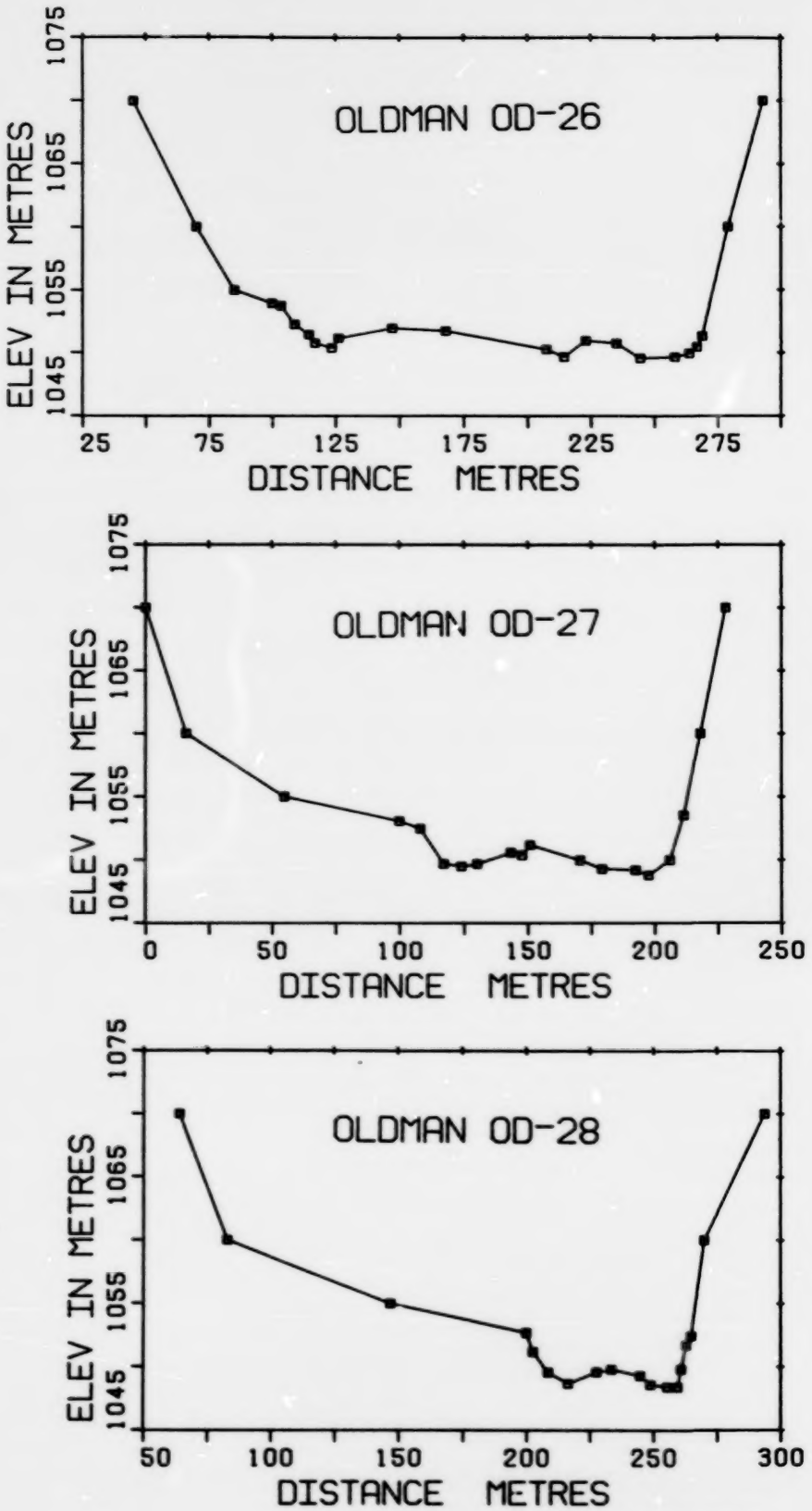
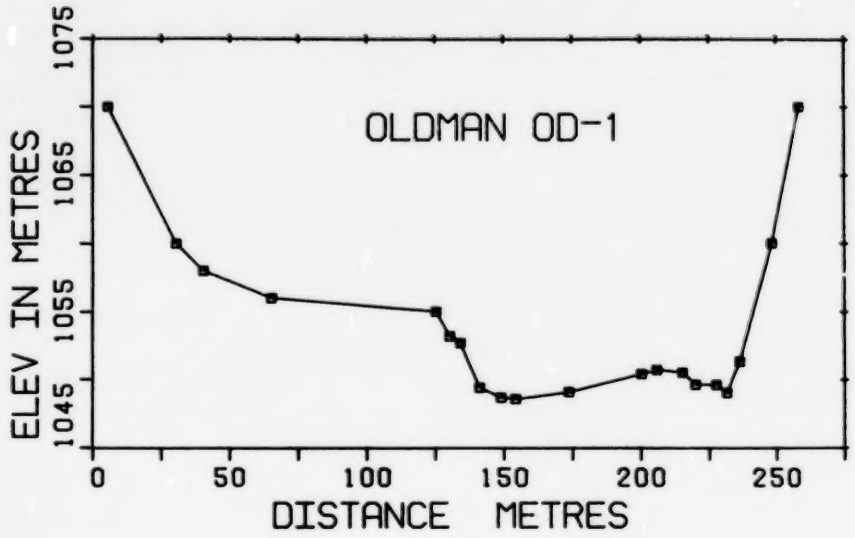
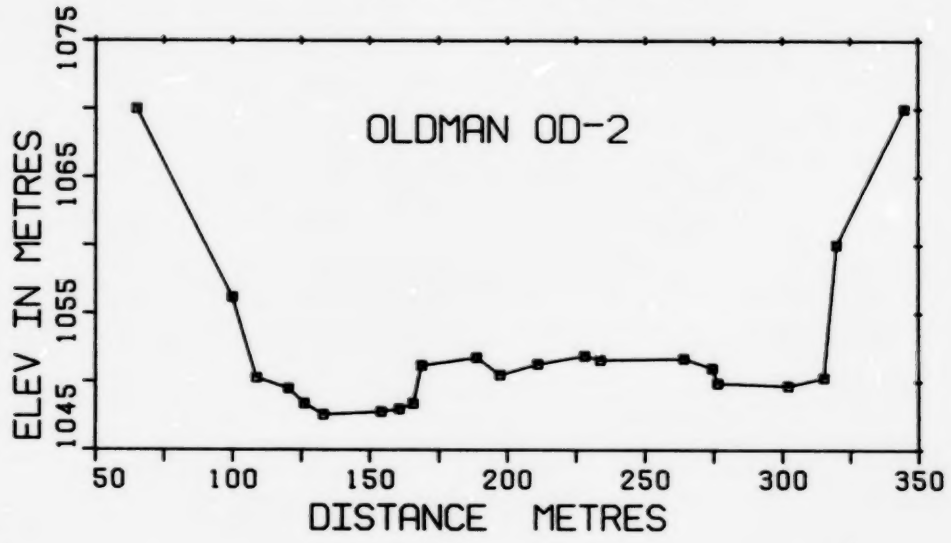

OLDMAN OD-26
ELEV IN METRES
1045
1055
1065
1075
25
75
125
175
225
275
DISTANCE METRES
OLDMAN OD-27
ELEV IN METRES
1045
1055
1065
1075
0
50
100
150
200
250
DISTANCE METRES
OLDMAN OD-28
ELEV IN METRES
1045
1055
1065
1075
50
100
150
200
250
300
DISTANCE METRES

FIGURE A.6


OLDMAN OD-1
ELEV IN METRES
1045
1055
1065
1075
0
50
100
150
200
250
DISTANCE METRES


OLDMAN OD-2
ELEV IN METRES
1045
1055
1065
1075
50
100
150
200
250
300
350
DISTANCE METRES

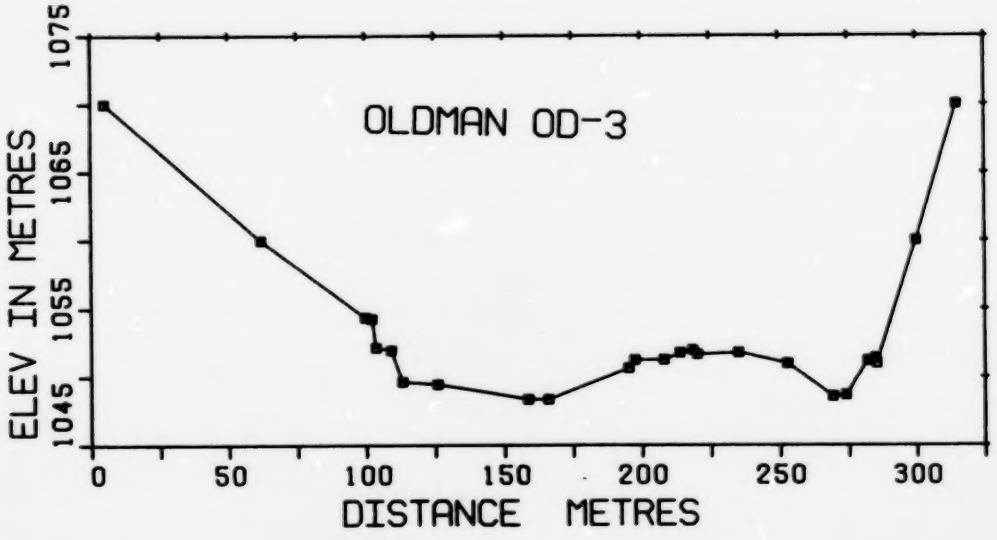
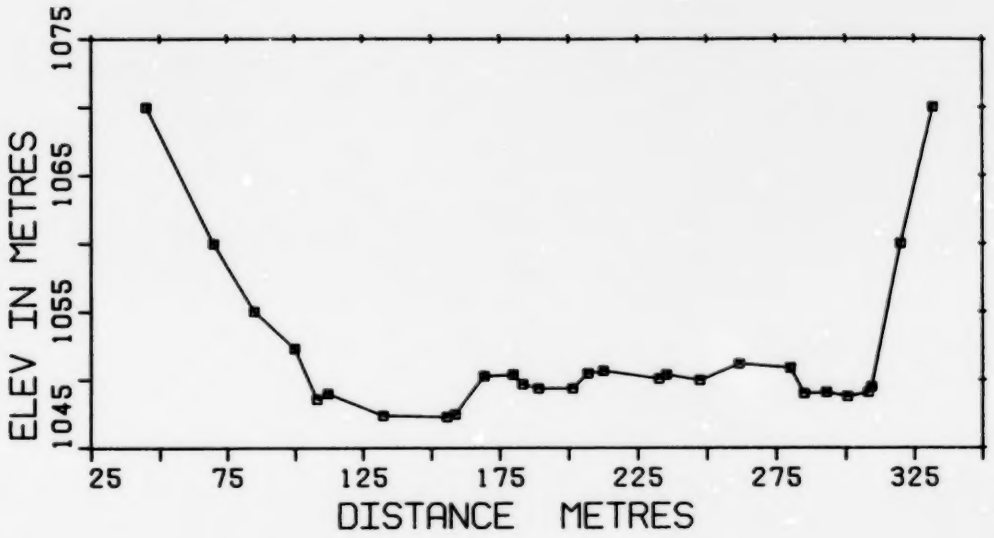
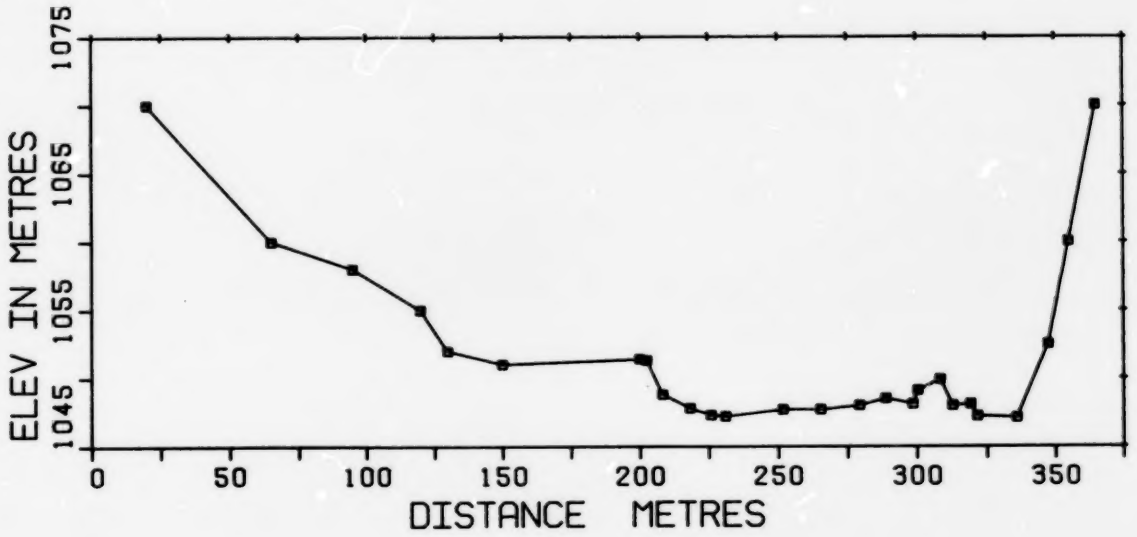

OLDMAN OD-3
ELEV IN METRES
1045
1055
1065
1075
0
50
100
150
200
250
300
DISTANCE METRES

FIGURE A.7

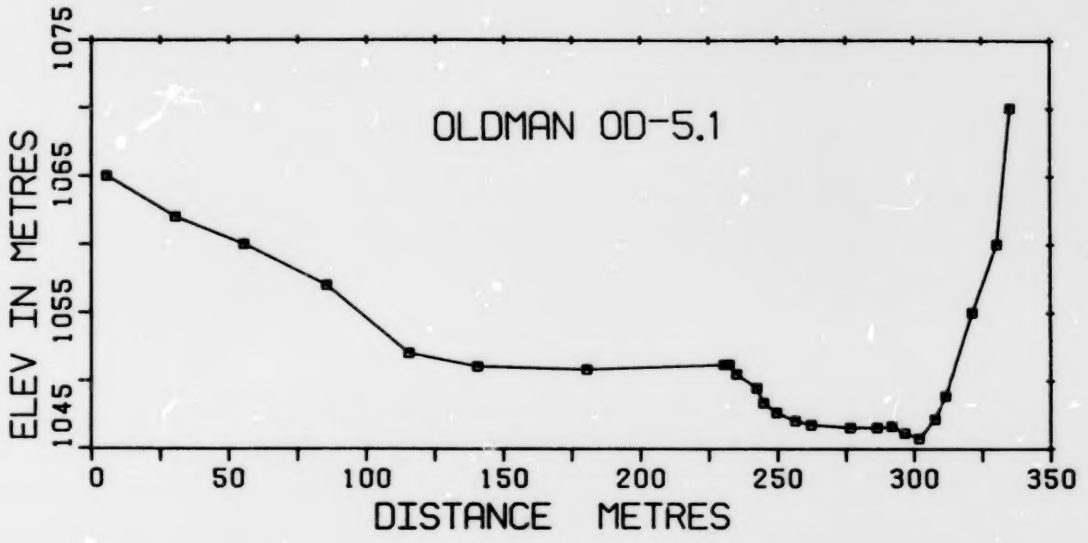


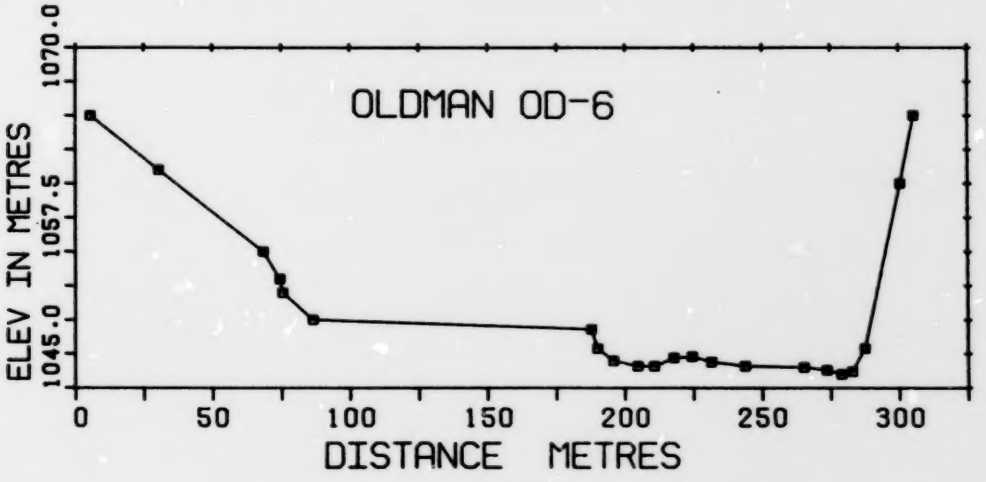
OLDMAN OD-4



OLDMAN OD-5

FIGURE A.8


OLDMAN OD-5.1
ELEV IN METRES
1045
1055
1065
1075
0
50
100
150
200
250
300
350
DISTANCE METRES


OLDMAN OD-6
ELEV IN METRES
1045.0
1057.5
1070.0
0
50
100
150
200
250
300
DISTANCE METRES

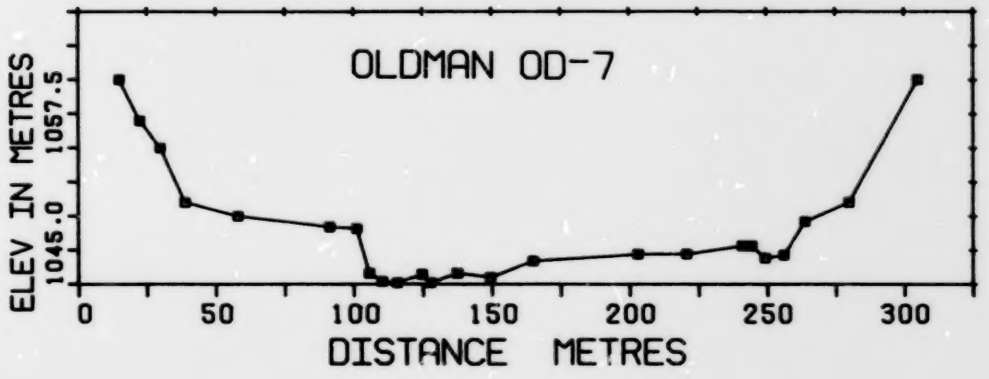
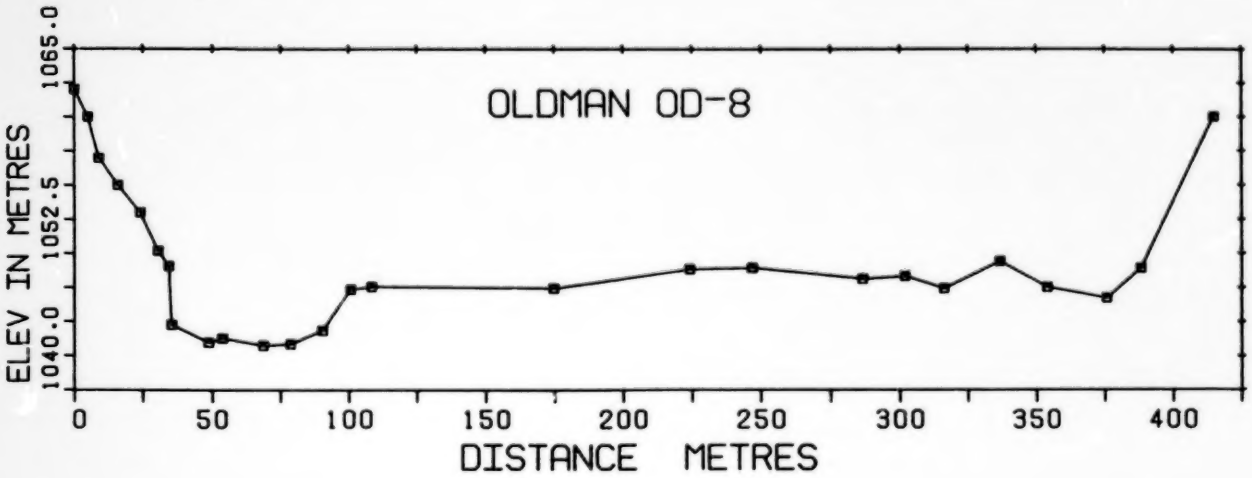
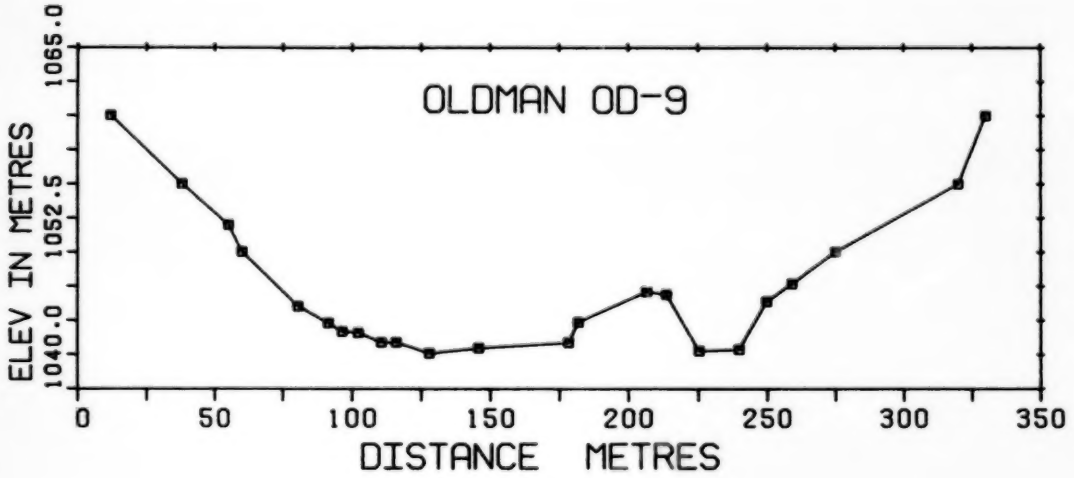

OLDMAN OD-7
ELEV IN METRES
1045.0
1057.5
0
50
100
150
200
250
300
DISTANCE METRES

FIGURE A.9


OLDMAN OD-8
ELEV IN METRES
1065.0
1052.5
1040.0
0
50
100
150
200
250
300
350
400
DISTANCE METRES


OLDMAN OD-9
ELEV IN METRES
1065.0
1052.5
1040.0
0
50
100
150
200
250
300
350
DISTANCE METRES

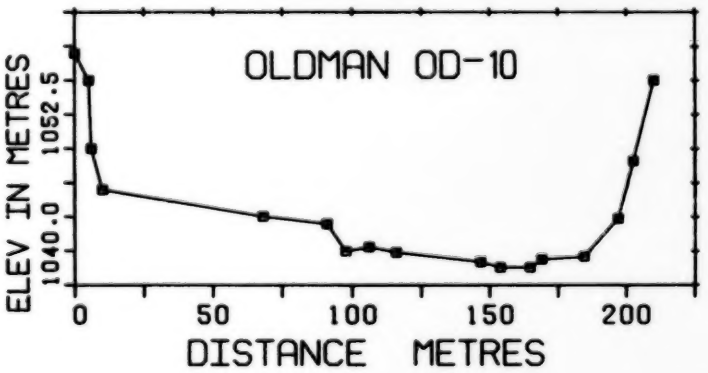
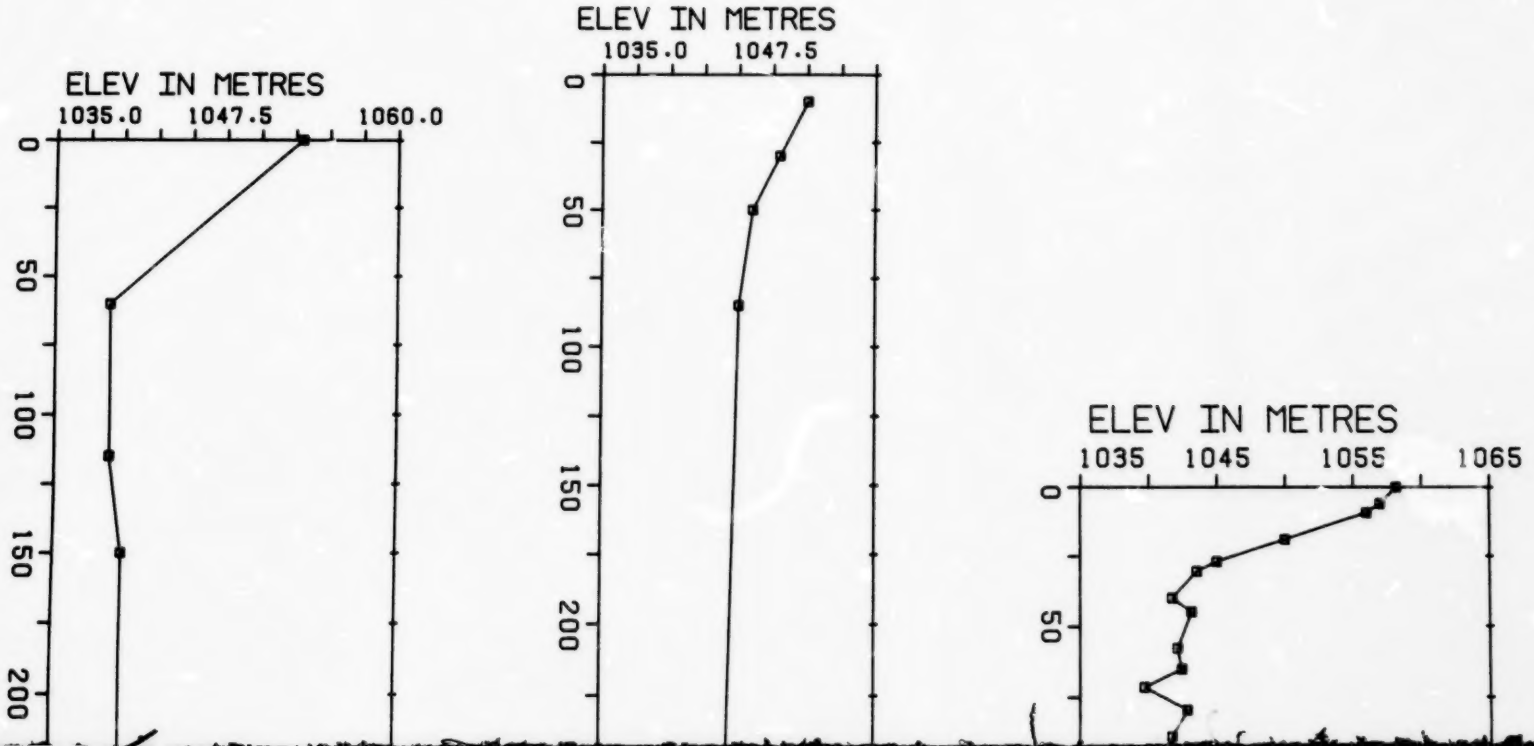

OLDMAN OD-10
ELEV IN METRES
1052.5
1040.0
0
50
100
150
200
DISTANCE METRES

FIGURE A.10


ELEV IN METRES
1035.0
1047.5
1060.0
0
50
100
150
200
ELEV IN METRES
1035.0
1047.5
0
50
100
150
200
ELEV IN METRES
1035
1045
1055
1065
0
50

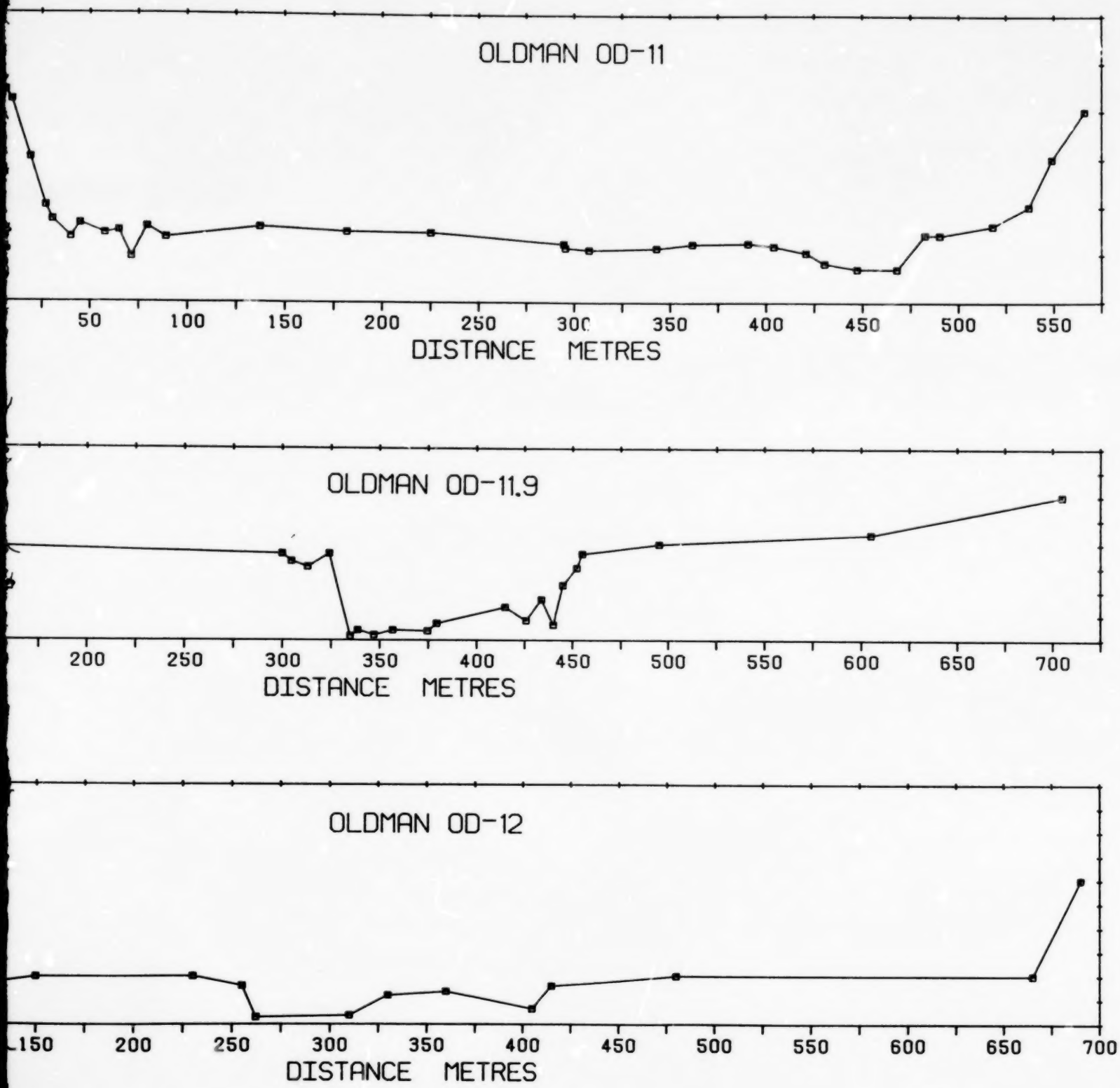
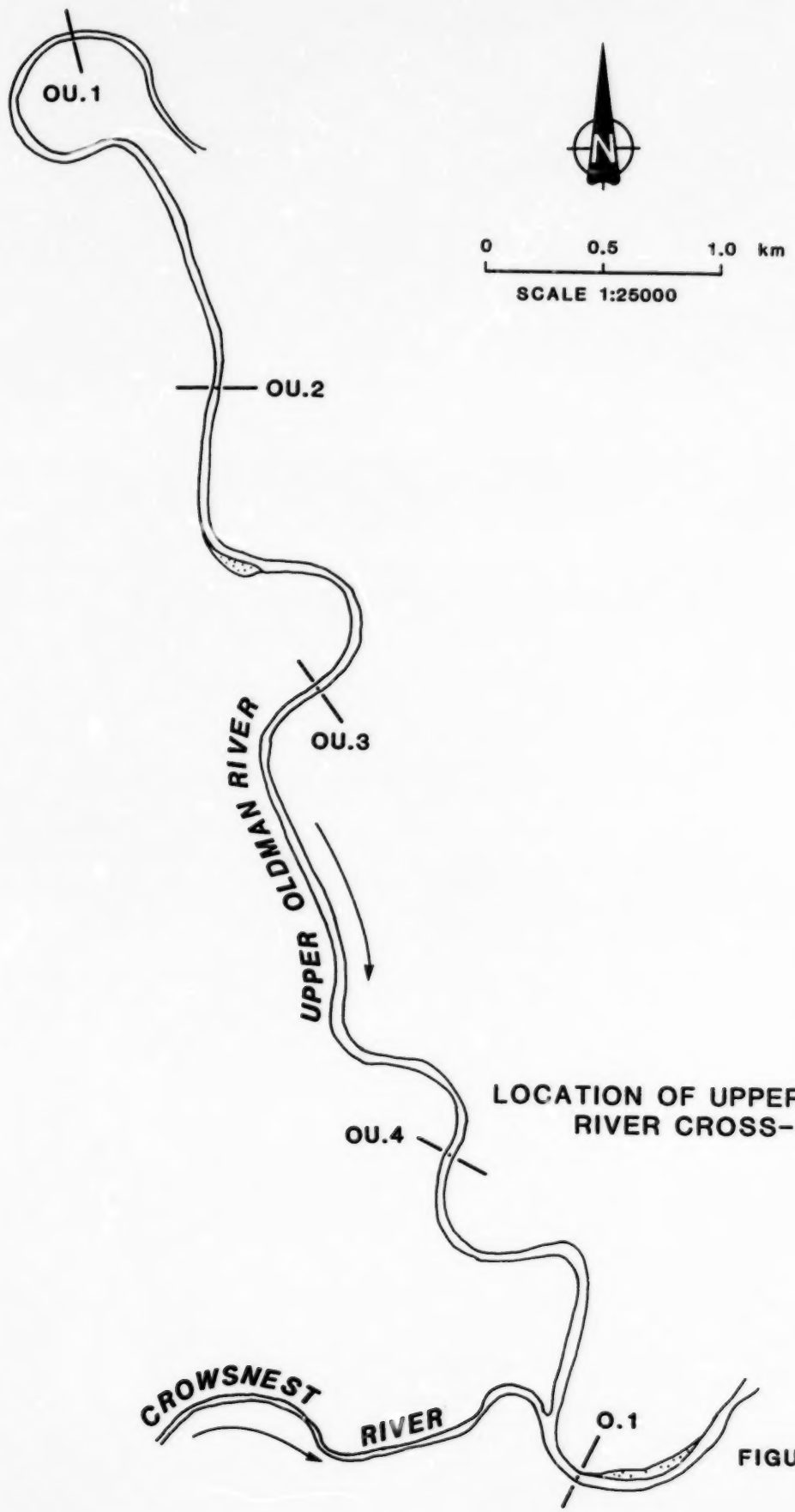

OLDMAN OD-11
50
100
150
200
250
300
350
400
450
500
550
DISTANCE METRES
OLDMAN OD-11.9
200
250
300
350
400
450
500
550
600
650
700
DISTANCE METRES
OLDMAN OD-12
150
200
250
300
350
400
450
500
550
600
650
700
DISTANCE METRES

FIGURE A.11



LOCATION OF UPPER OLDMAN RIVER CROSS-SECTIONS

FIGURE A.12

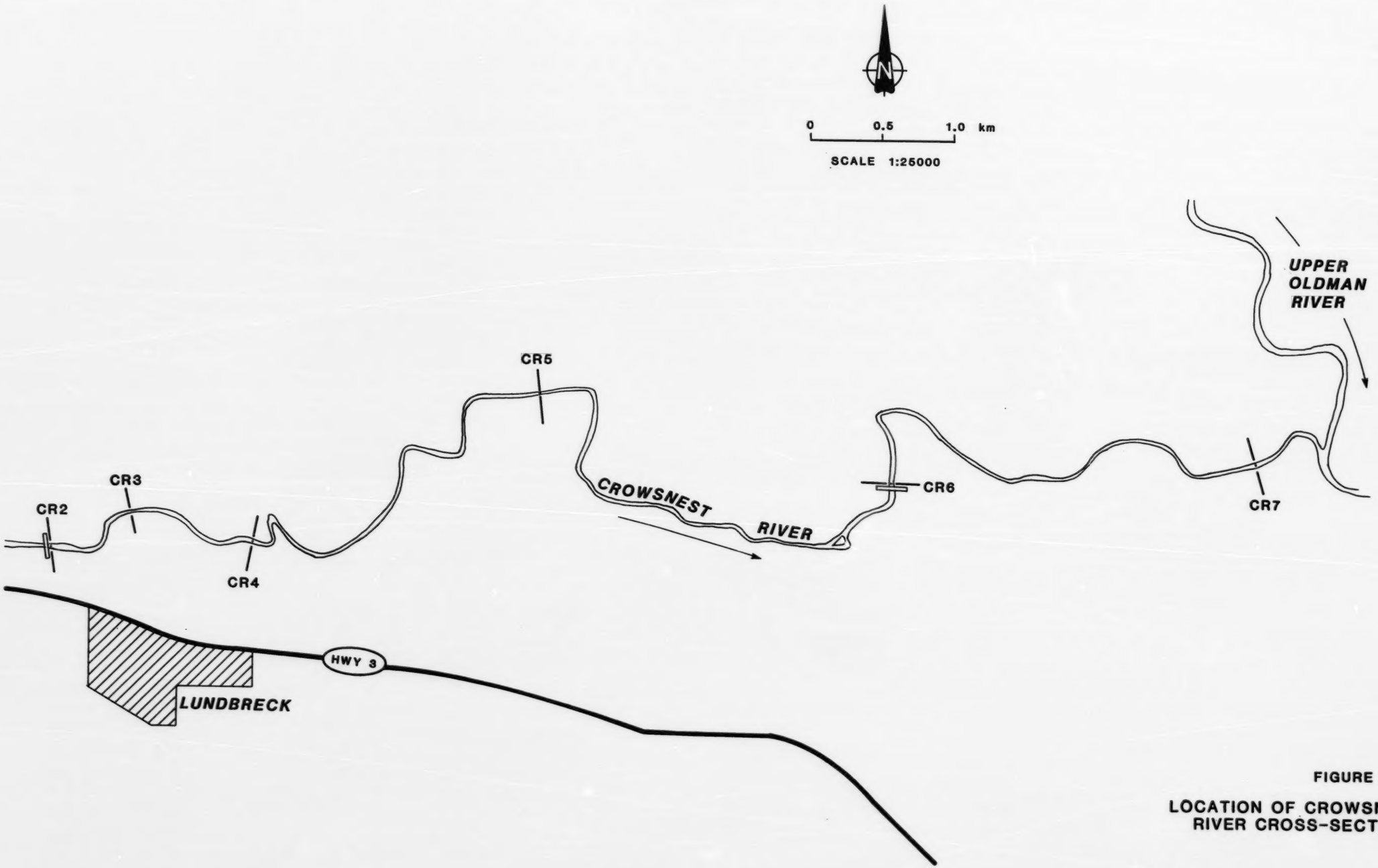


FIGURE A.13

LOCATION OF CROWSNEST RIVER CROSS-SECTIONS

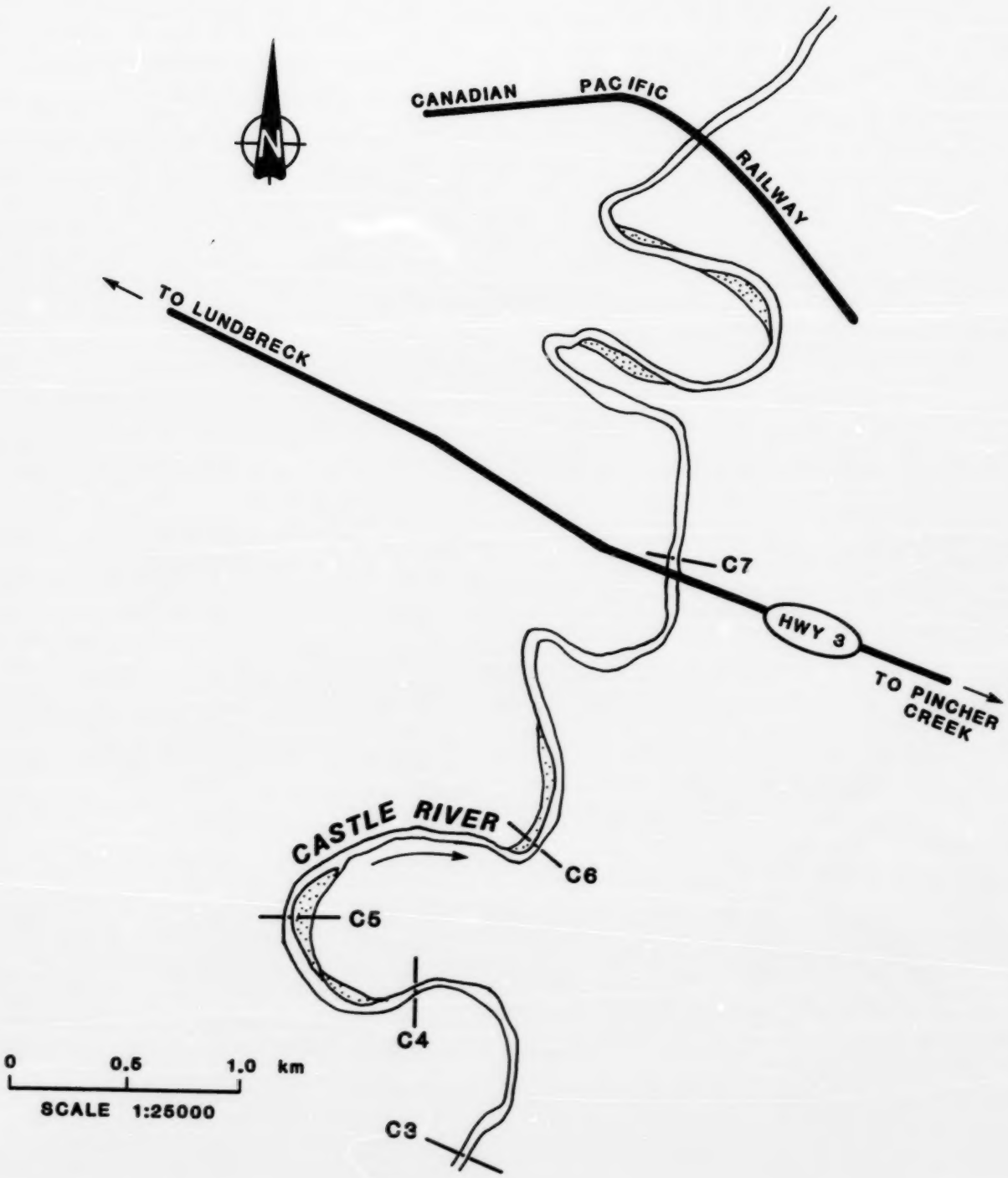
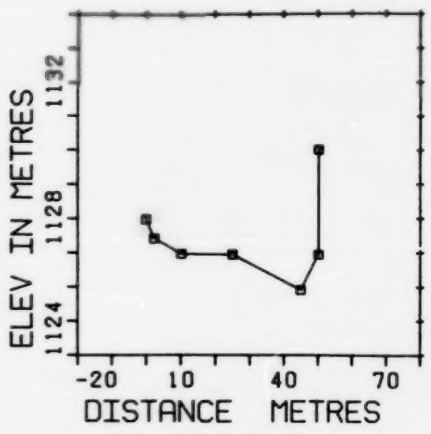
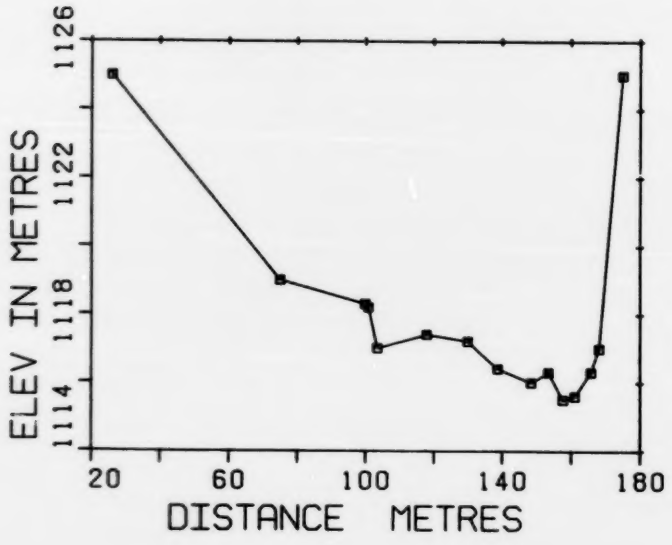


FIGURE A.14

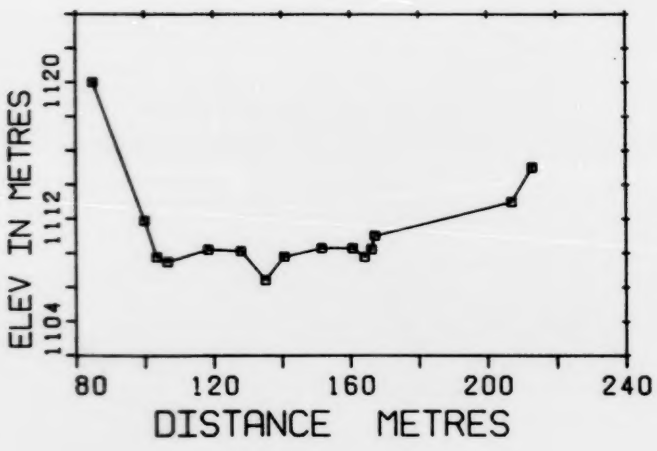
LOCATION OF CASTLE RIVER CROSS-SECTIONS



OLDMAN R U/S OU-1

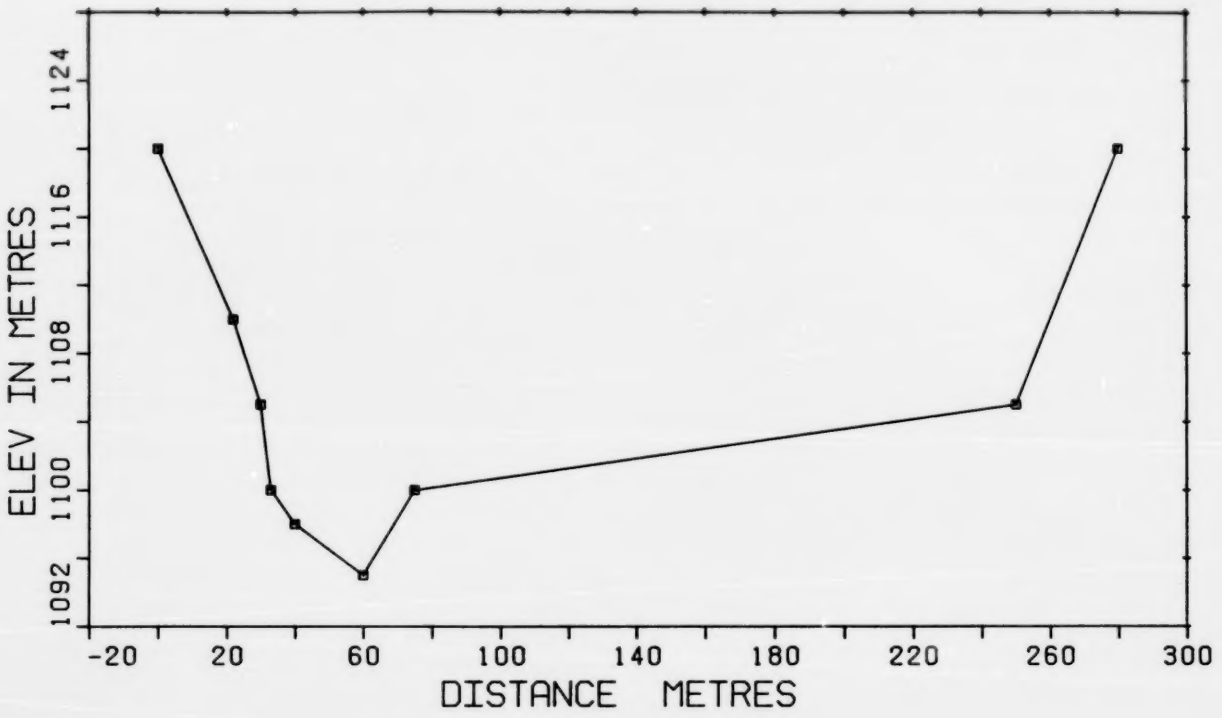


OLDMAN R U/S OU-2

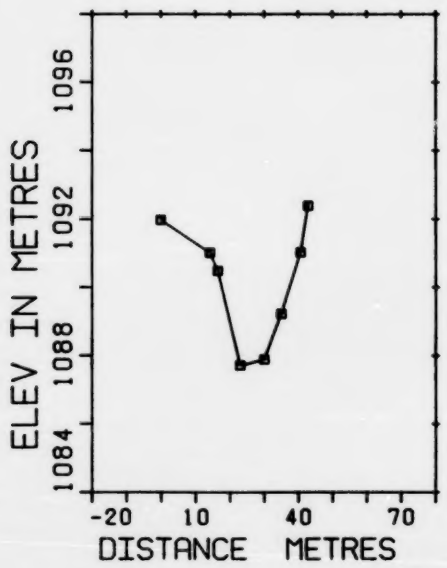


OLDMAN R U/S OU-3

FIGURE A.15

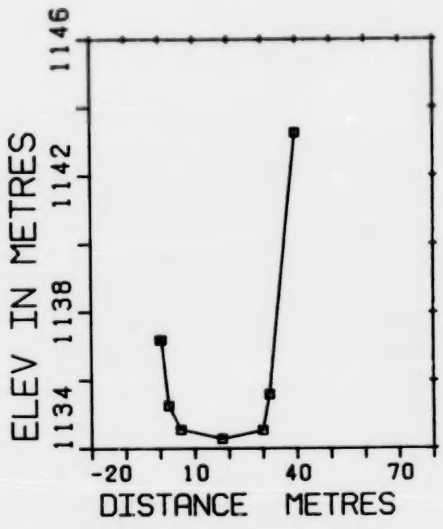


OLDMAN R U/S OU-4

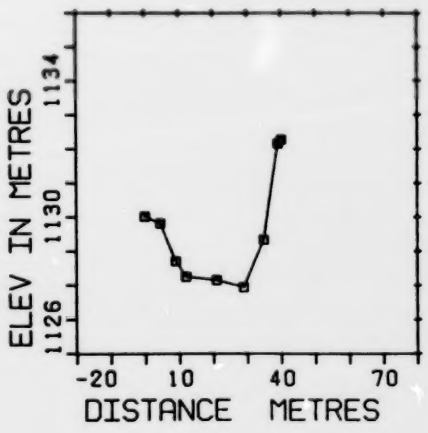


OLDMAN R U/S O-1

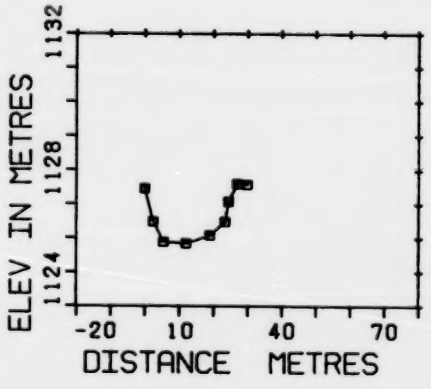
FIGURE A.16



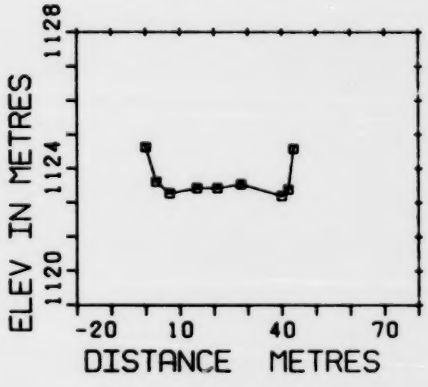
CROWSNEST R CR-1



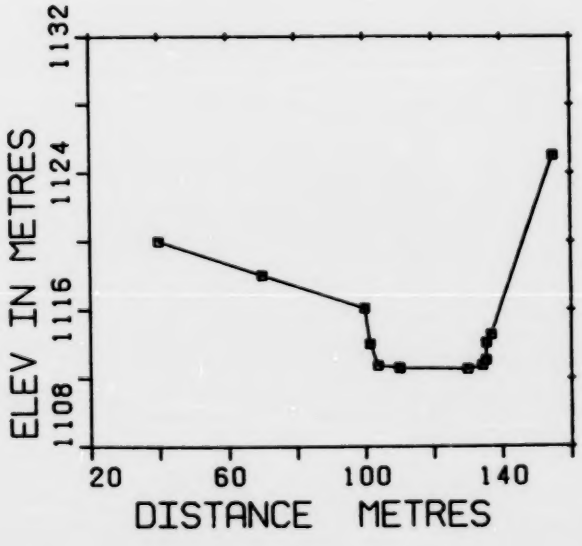
CROWSNEST R CR-2



CROWSNEST R CR-3

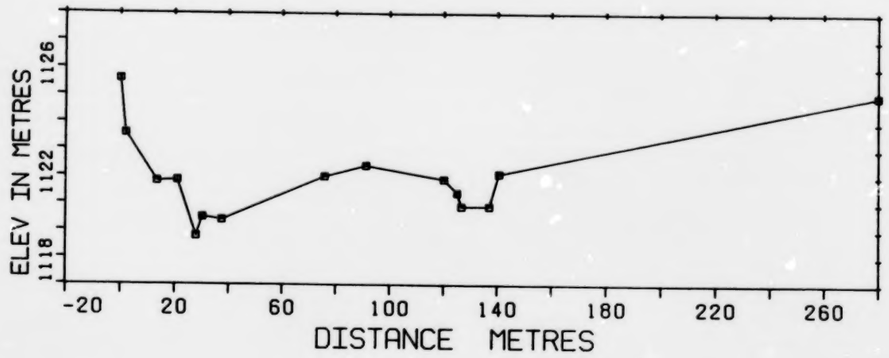


CROWSNEST R CR-4

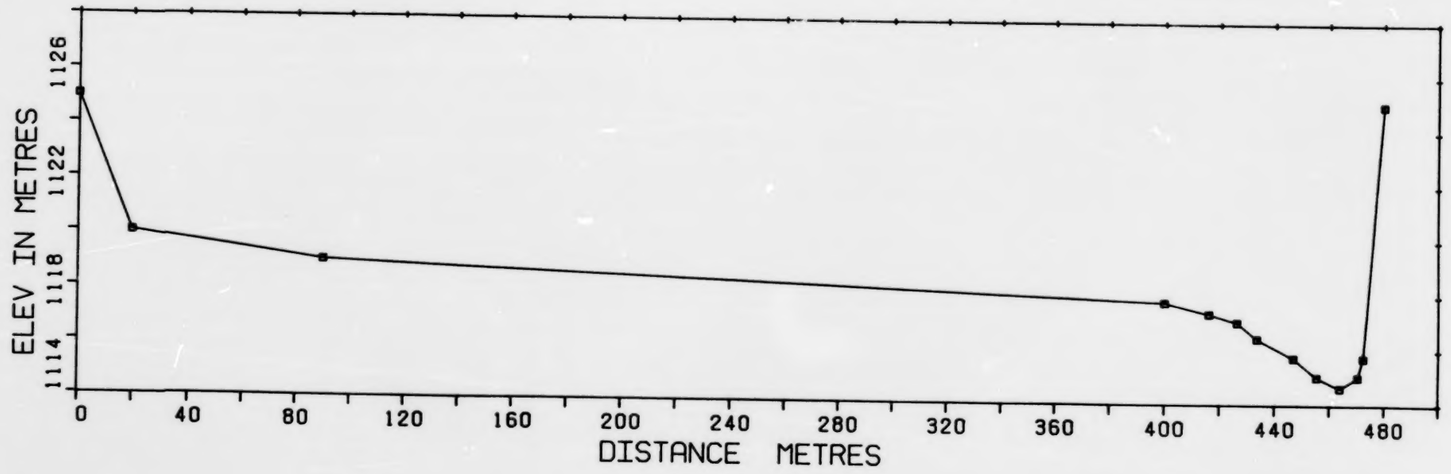


CROWSNEST R CR-5

FIGURE A.17

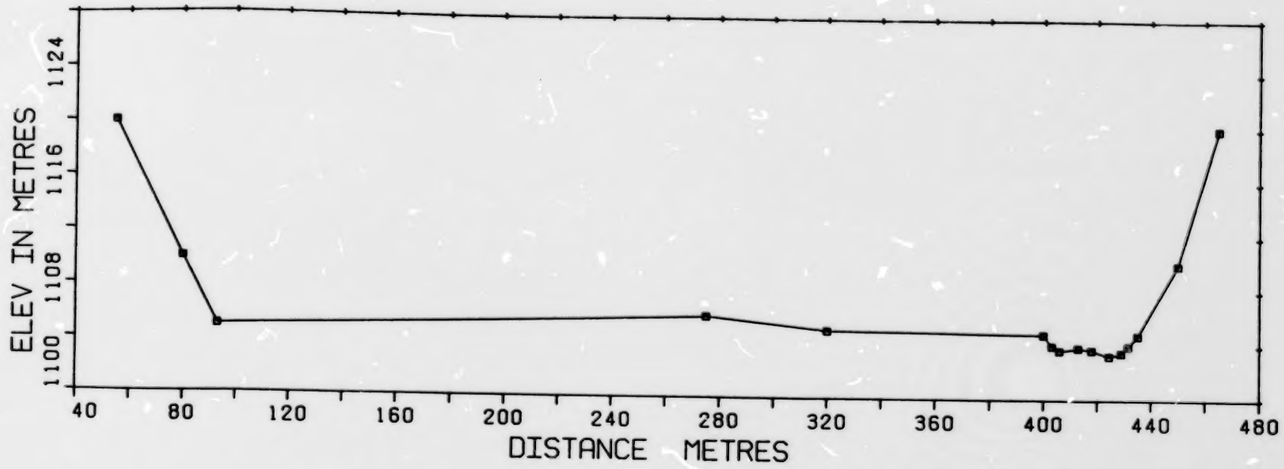


CASTLE R C-5

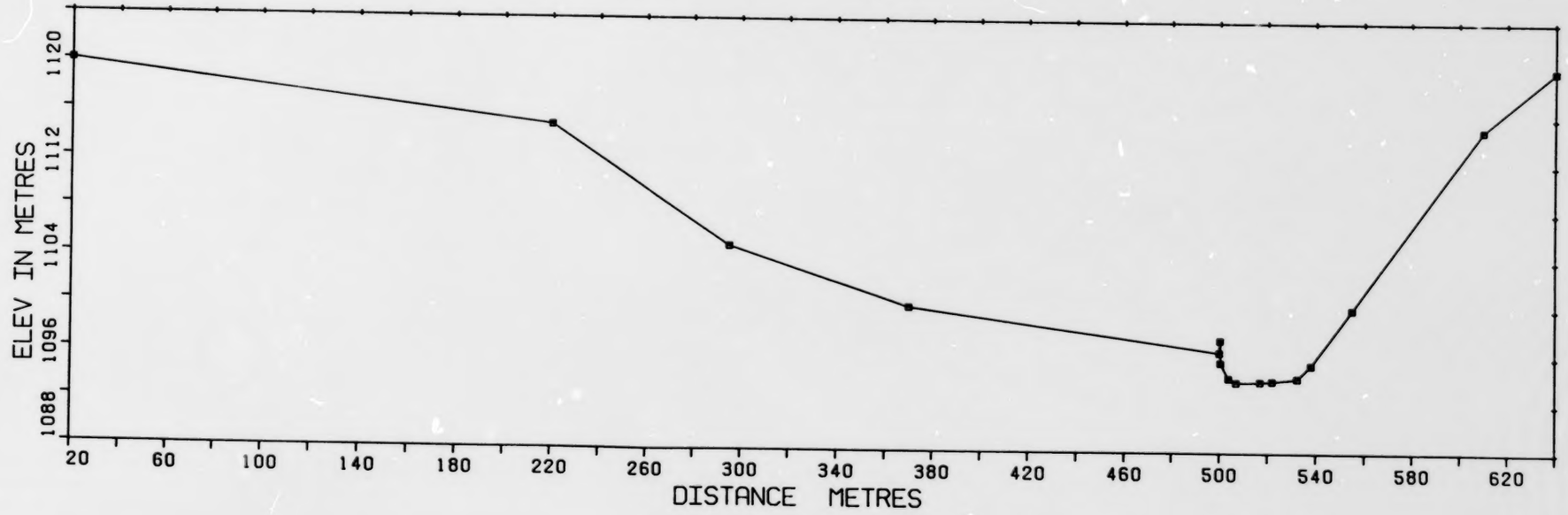


CASTLE R C-6

FIGURE A.18

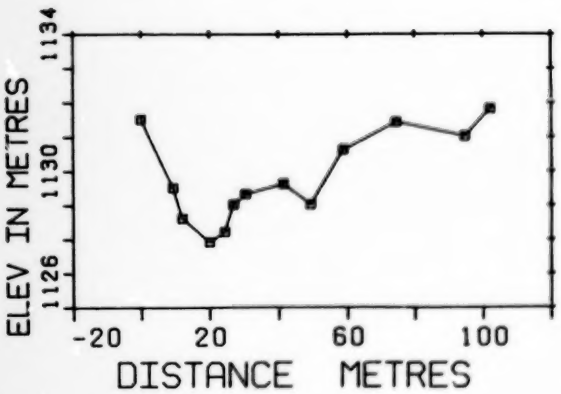


CROWSNEST R CR-6

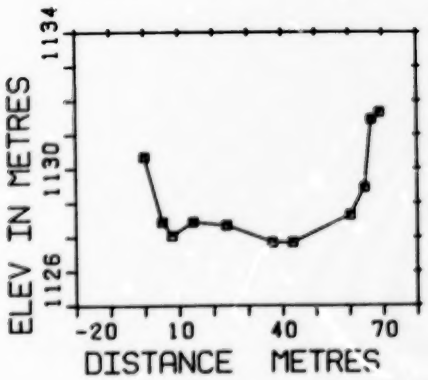


CROWSNEST R CR-7

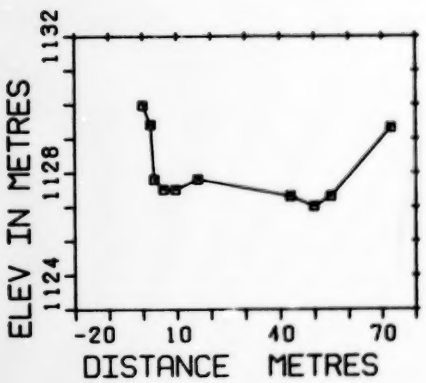
FIGURE A.19



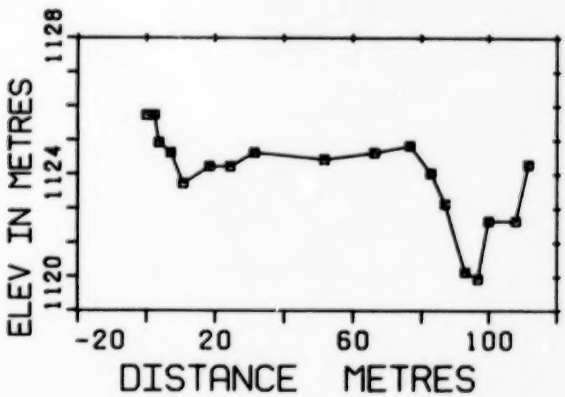
CASTLE R C-2



CASTLE R C-2A

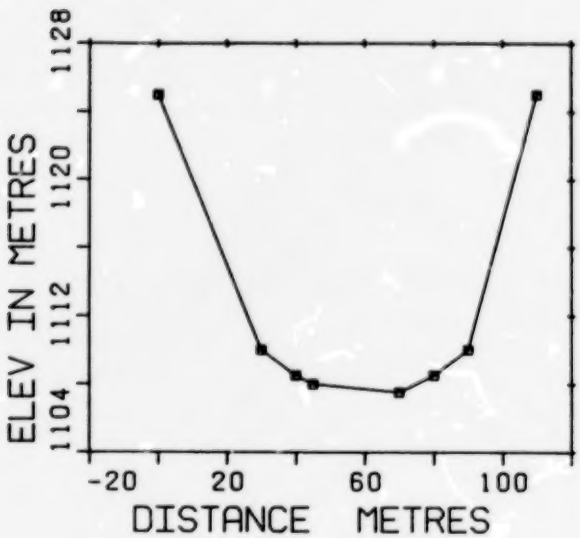


CASTLE R C-3



CASTLE R C-4

FIGURE A.20



CASTLE R C-7

FIGURE A.21

APPENDIX B

1985 SUSPENDED SEDIMENT MEASUREMENTS ON TRIBUTARY STREAMS IN THE VICINITY OF THE CONFLUENCES

On 23 May 1985, NHCL collected suspended sediment water samples on the tributary streams in the vicinity of the confluences. Unfortunately, this was not at the time of the annual maximum discharge. The results are given below:

River	Discharge m^3/s	Suspended Sediment Concentration mg/l	Suspended Sediment Load kt/d
Upper Oldman	25	84	0.18
Crowsnest	14	27	0.033
Castle	92	55	0.44
Total	131		0.65

The distribution of flow between the three streams does not correspond to the mean discharge data of Table 1 (main report). The data indicate, however, that concentrations in the Oldman are much higher than in the other two streams during average May flow conditions. (The mean May discharge at Brocket is 132 m^3/s whereas on the sampling day it was 131 m^3/s.)

If the measured concentrations are assumed to represent average concentrations during May and June (when 91% of the annual sediment load occurs) then the split in the sediment load between the three tributaries is estimated as follows:

Tributary	Percent of Annual Sediment Load
Upper Oldman	57
Crowsnest	6
Castle	37
	100

On this basis, however, the average annual total is only 58 kt, which is only 22% of the measured average for the period 1966 through 1983.

APPENDIX C

OLDMAN RIVER BED MATERIAL SAMPLES

Sampling Program

Samples of Oldman River bed material below the dam site were collected on 27 and 28 June and 6 August 1985 by Northwest Hydraulic Consultants Ltd. with the assistance of Golder Associates. The location of surface and sub-surface samples are shown in Figure C.1.

Surface Samples

The method used for sampling surface materials was to take a photograph of 600 x 600 mm grid placed on the bed material surface, the grains immediately below the grid points constituted the sample. Three samples were taken at the following locations:

- Sample S.1 — One kilometre downstream of the dam axis (approximately the diversion tunnel outlet);
- Sample S.2 — Approximately 1.5 km downstream of the dam axis, at the location of Test Pit TP85H003; and
- Sample S.3 — Approximately 7 km downstream of the dam axis, and 0.1 km downstream of the Brocket bridge.

Photo 10 in the main report shows the photo sample S.1, the sample photographs were analysed using the grid-by-

number procedure as outlined by Kellerhals and Bray (1971), the results being equivalent to a bulk sieve analysis.

Figure C.2 shows the grain size distribution curves of the three samples. There is minimal variation in size between the three samples which are classified as coarse gravel and cobbles with a median size of 85 mm.

Sub-Surface Samples

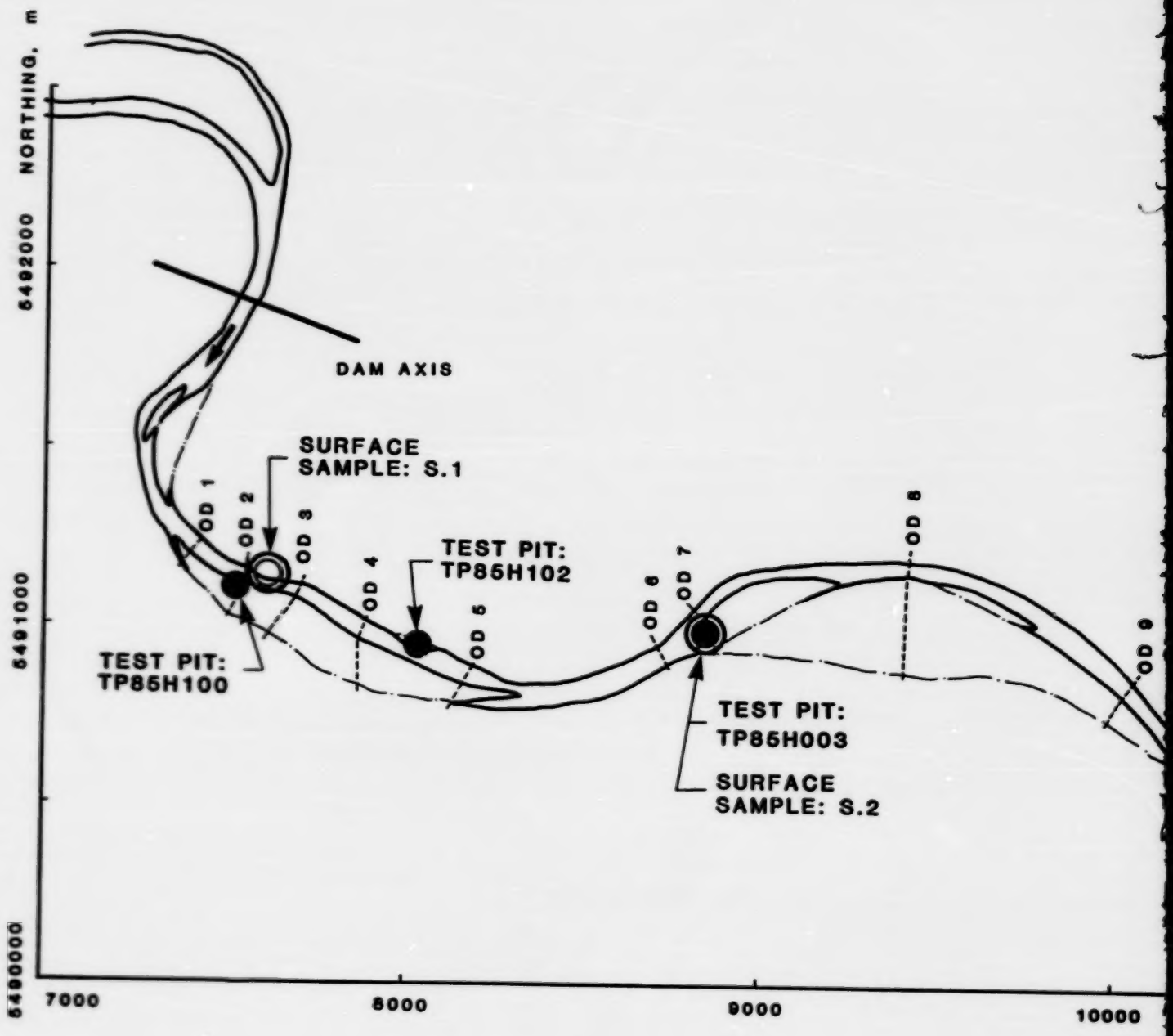
Sub-surface samples were collected from test pits dug in the river bed using a backhoe. Photos 6 and 7 show the backhoe in operation. Three pits were dug at the following locations:

- TP85H100. Right side of channel 0.9 km downstream of dam axis;
- TP85H102. Left side of channel 1.5 km downstream of dam axis; and
- TP85H003. Right side of channel 2.4 km downstream of dam axis.

Bulk samples were taken at depths of approximately 0.5, 1.0 and 2.0 m to enable determination of the material size at various levels. (Two metres was approximately the maximum depth to which the pits could be dug before the sides collapsed, except for TP85H100, where bedrock was encountered at a depth of 1.9 m).

The size of the material samples were determined either by sieve analysis or by grid-by-number analysis of sample photographs. Photo 8 shows the material obtained at a depth of 2.0 m from TP85H003.

Figures C.3 through C.5 show the grain size distribution curves of the samples from the three test pits, (three samples per pit). The curves show that the size of the materials is consistent both at different elevations within the same pit and from pit-to-pit. The materials are classified as coarse gravel and cobbles with a median size of 58 mm.


5492000 NORTHING, m
5491000
5490000
7000
8000
9000
10000
EASTING, m
DAM AXIS
SURFACE SAMPLE: S.1
TEST PIT: TP85H102
TEST PIT: TP85H100
TEST PIT: TP85H003
SURFACE SAMPLE: S.2
OD 1
OD 2
OD 3
OD 4
OD 5
OD 6
OD 7
OD 8
OD 9

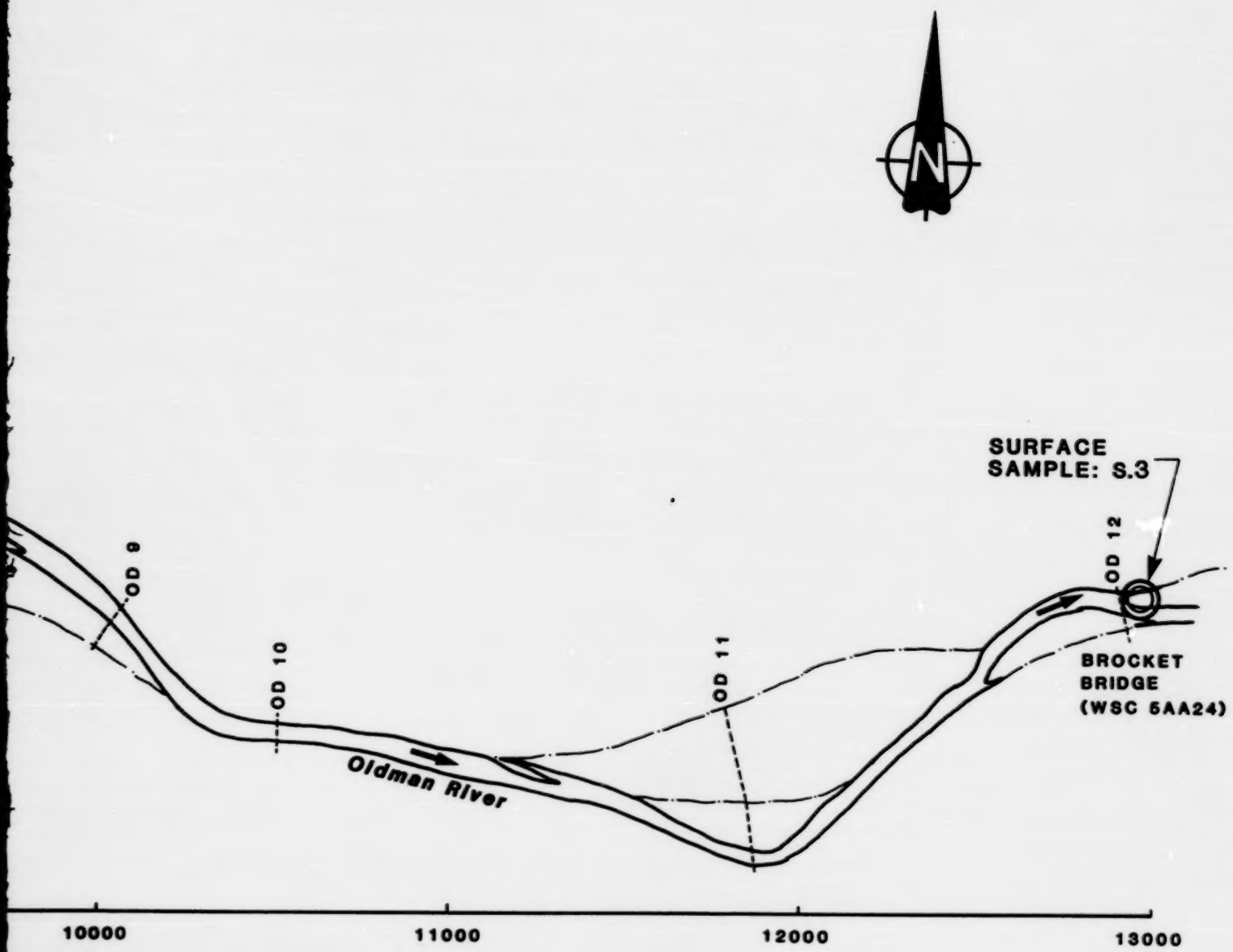
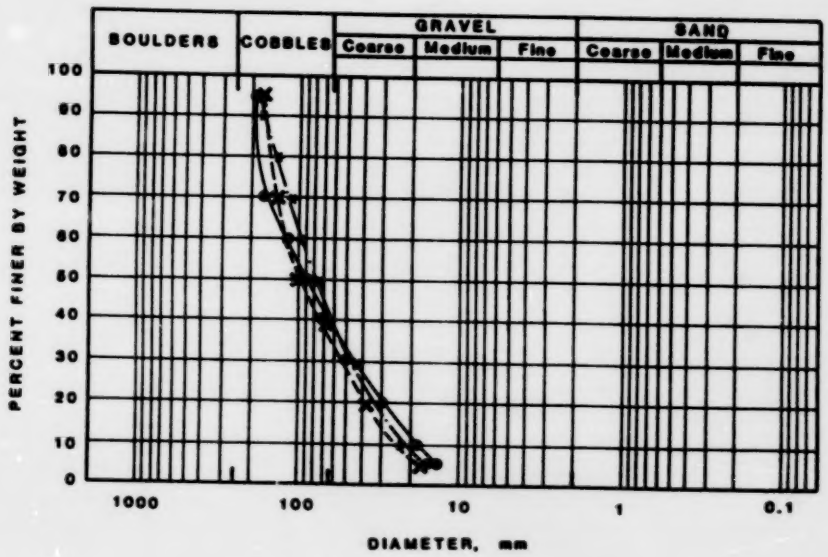


FIGURE C.1

LOCATION OF BED
MATERIAL SAMPLES



LEGEND:

SAMPLE S.1

SAMPLE S.2

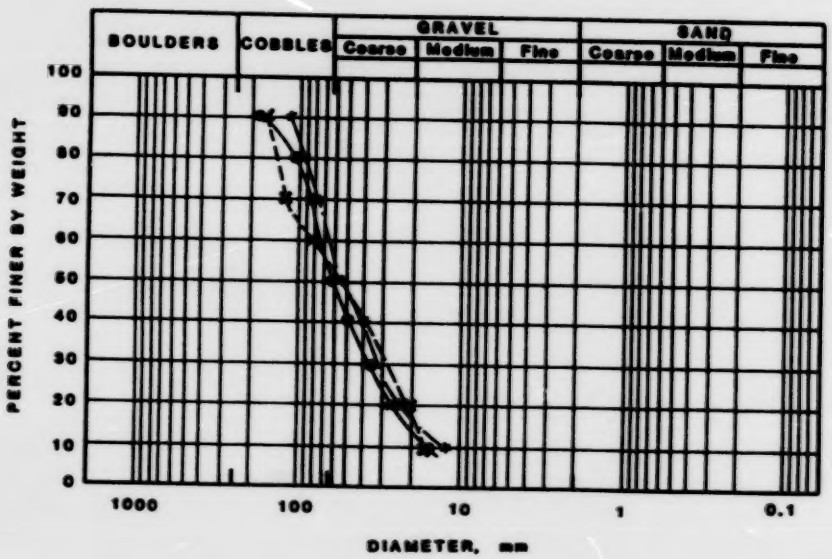
SAMPLE S.3

NOTES:

- SEE FIGURE II.1 FOR LOCATION OF SAMPLES
- GRAIN SIZE DISTRIBUTION BY GRID-BY-NUMBER FROM PHOTOGRAPH OF SAMPLE.

FIGURE C.2

OLDMAN RIVER
SURFACE BED MATERIAL



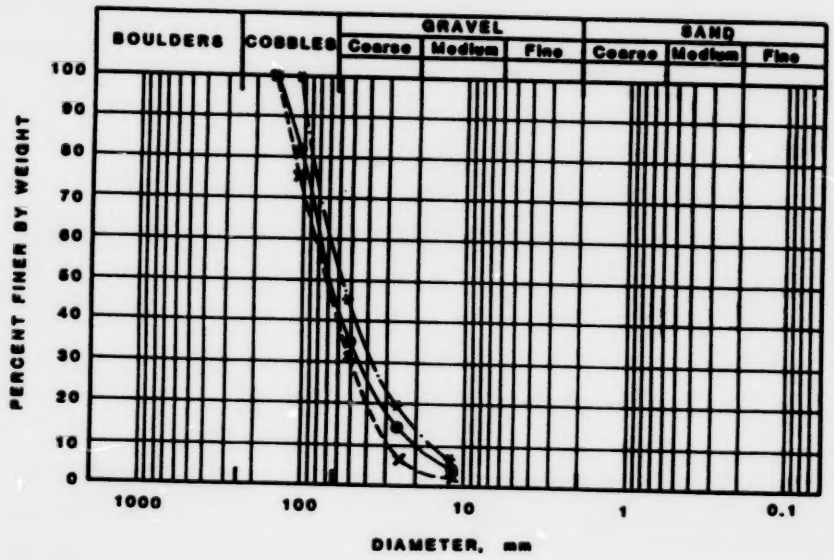
LEGEND:	DEPTH BELOW SURFACE, m	ELEVATION OF SAMPLE, m
●——●——●	0.5	1048.9
×– – –×– – –×	1.0	1048.4
●—·—●—·—●	2.0	1047.5

NOTES:

- SEE FIGURE II.1 FOR LOCATION OF TEST PIT.
- GRAIN SIZE DISTRIBUTION OBTAINED BY GRID-BY-NUMBER FROM PHOTOGRAPH OF SAMPLE.
- BEDROCK (SANDSTONE) AT EL. 1047.2m.

FIGURE C.3

OLDMAN RIVER
SUB-SURFACE BED MATERIAL
TEST PIT TP85H100



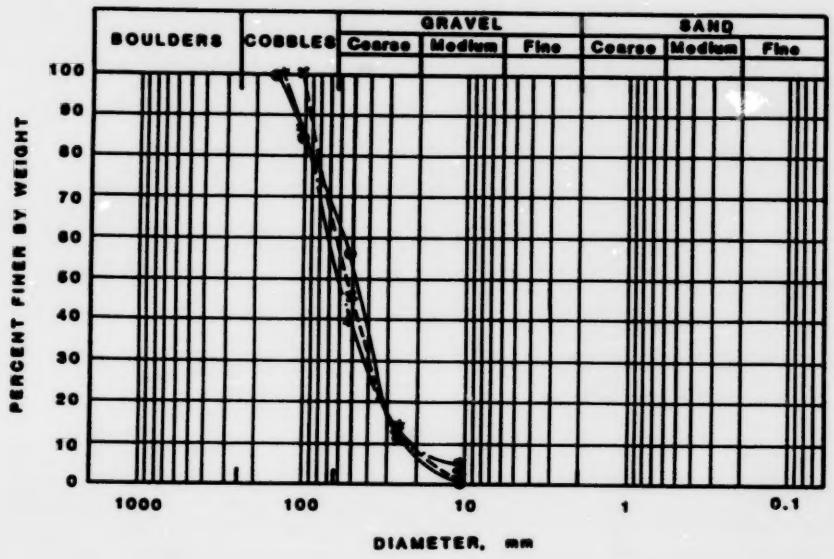
LEGEND:	DEPTH BELOW SURFACE, m	ELEVATION OF SAMPLE, m
●——●——●	0.5	1047.8
×– – –×– – –×	1.0	1047.3
×——·——·—×	2.0	1046.3

NOTES:

- SEE FIGURE II.1 FOR LOCATION OF TEST PIT.
- GRAIN SIZE DISTRIBUTION OBTAINED BY WEIGHING SAMPLE.

FIGURE C.4

OLDMAN RIVER
SUB-SURFACE BED MATERIAL
TEST PIT TP85H102



LEGEND:	DEPTH BELOW SURFACE, m	ELEVATION OF SAMPLE, m
●——●——●	0.5	1046.4
×– – –×– – –×	1.0	1045.9
●—·—●—·—●	2.0	1044.9

NOTES:

- SEE FIGURE II.1 FOR LOCATION OF TEST PIT.
- GRAIN SIZE DISTRIBUTION OBTAINED BY WEIGHING SAMPLE.

FIGURE C.5

OLDMAN RIVER
SUB-SURFACE BED MATERIAL
TEST PIT TP85H003